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"A MACHINE OF PRECISION"

It will probably come as a surprise to readers to find that the above title, in quotes, refers to the steam locomotive, the old-fashioned "Puffing Billy," that is now, at long last, to be displaced on the railways of Britain by modern electrics and diesels. Yet such was the title of Mr. K. J. Cook's Presidential Address to the Institution of Locomotive Engineers, delivered on September 21st. The myth of a primitive machine dies hard where the steam locomotive is concerned. Prior to the war of 1939–45, when Mr. Cook was Locomotive Works Manager at Swindon, there was a considerable body of industrial opinion that regarded the railway workshops as a collection of antiquated establishments quite incapable of making any contribution to the needs of precision manufacture of war material. Industry in general and officialdom in particular had no idea of the wide range of manufacturing capacity needed on a great railway. Mr. Cook told of the astonishment of the productive Ministries when they found what could be done, and how one official exclaimed, "You have the finest toolroom outside the aircraft industry." But in what way is precision built into a steam locomotive, and why should such attention to manufacturing and maintenance problems be given when the machine itself is so soon to be superseded altogether? As Mr. Cook said in his opening remarks, some might nowadays consider that with any paper dealing with the steam locomotive "Senile Decay" might be a more appropriate title! But as we have pointed out on several occasions since the announcement of the British Transport Commission's plan for the modernisation of British Railways, the changeover period is going to be a very difficult one, and there is much that remains for the steam locomotive to do before its final demise.

It is interesting to hear Mr. Cook's opinion that the technique of constructing and maintaining steam locomotives on British Railways is now at the summit of accuracy. He speaks from a very wide experience, not only of his long and distinguished service on the Great Western, but more recently from his present position as Chief Mechanical and Electrical Engineer of two Regions of British Railways simultaneously, the Eastern and the North Eastern. As he emphasises, the economical criterion of locomotive performance is the cost per mile in similar conditions of operating, and towards this one of the greatest contributory factors is the mileage run between heavy repairs. In carrying out a heavy repair the dismantling and erecting costs are fairly constant whatever the mileage, and a higher mileage enables their costs to be spread and to produce a lower overall figure. The peculiar and unique basic mechanism of the ordinary steam locomotive, in which the power is transmitted through two, three, or more axes, the centres of which are partly fixed, but are subject to considerable movement relative to their locations and to each other, invites the question as to whether basic accuracy in construction is really desirable; there might be a temptation to indulge in slack fits, and methods of alignment that have a touch of the mediæval. On the other hand, the greater the initial accuracy the lower will be the maximum stresses set up in components; initial tolerances in working parts can be reduced, and this, of course, reduces the hammering effect in bearings and the rate at which wear and slackness develop.

It was during Mr. C. B. Collett's time as Chief Mechanical Engineer of the Great Western Railway that the practice was introduced of optical alignment of cylinder centre lines, and the precision setting of horn centres relative to each other, together with the length of coupling rods and the throw and angle of crank pins. With this magnificent tool available Swindon works were able to precision-build and precision-repair locomotives, with the excellent results in road performance that became so well known before the war of 1939–45, and are continued to-day. As Mr. Cook remarks: "If and when the steam locomotive fades away in this country, it will not be on account of any decline in the excellence of its mechanism." But a number of factors have combined to bring a point in the history of this country at which the steam locomotive must decline, and in considering the changeover now forecast it is only natural to have doubts about the capacity of the railway shops to adjust themselves adequately to the new skills required. It is in this respect that Mr. Cook's address is so reassuring. In referring to several special tasks carried out in railway shops during the war he is almost certainly drawing upon his own experience at Swindon; but no doubt parallel cases could be found at Crewe and Derby, at Ashford and Eastleigh, and at the two great works now under Mr. Cook's direct control—Darlington and Doncaster. The

quest for mechanical efficiency continues, and just as the railway shops turned with facility to new and unaccustomed items of production during the war, so equally to-day Mr. Cook believes they will be able to turn to any alternative mechanism for railway use. Of the shops that have made the steam locomotive a machine of precision he concluded : " If, for example, it is necessary to chase a tenth of a thou. round the plunger or bore of a diesel engine fuel pump or injector, that tenth can be found in a locomotive workshop on British Railways." We have no doubt of it. But we hope that the possession of that ability will not lead British Railways to assume that since steam locomotives are built in its workshops the appropriate place to build diesels will also be in those shops. There are great and growing export markets for diesel locomotives. Only the private locomotive building firms can enter them. It would be of great assistance to those firms in retaining their export markets and entering new ones were they able to count confidently upon a flow of orders from British Railways, able to stress to prospective oversea customers how much experience they had gained at home, and able, possibly, to lay themselves out, having an assured market, for high production.

WORLD TRADE AND BRITAIN'S SHARE

For some time the fact that the United Kingdom's share in world trade has been shrinking has been giving concern to economists. The September issue of the *Bulletin for Industry* abstracts a number of statistics that have a bearing upon the point, apparently with the object of convincing British industry that it should show more interest than in fact it does in Continental markets. It first points out that if all nations other than the U.S.A., Canada, the United Kingdom, non-sterling O.E.E.C. countries, and Japan (excluding altogether from consideration the U.S.S.R., Eastern European countries and China) are regarded as primary producers of food and raw materials then two-thirds of U.K. exports go to those primary producers, whereas only a half of U.S.A. exports go to them and merely one-third of Germany's. But of the total world increase of trade over the last six years—it has been increasing at a rate of between 6 and 7 per cent annually —intra-Continental trade and trade between the Continent and primary producers accounts for nearly three-fifths ; and the European market has expanded its power to absorb imports much more markedly than has the sterling area. In short, the Continent of Europe has continued to recover from the war ; and it is the more fully developed parts of the world, rather than backward areas, that provide not only the larger but the more rapidly expanding markets for imports and, therefore, for Britain's exports. The conclusion is drawn that " it would be dangerous to our future prospects . . . to assume that the Continent of Europe is not our market, but Germany's. . . . If we are to finance our rising import bill we must take every opportunity of expanding our share of the growing markets for manufactured goods, amongst which, if present trends continue, North America and Western Europe are likely to show the most rapid rates of increase. We must be flexible enough to move with expanding markets quickly, and not merely wait for prospects in our traditional markets to improve."

The argument is sound enough. For it is certainly true that an expanding Continental market able to absorb engineering exports from Germany should equally be capable of absorbing similar exports from this country. Yet a similar condition existed before the war. Even in a depression fully industrialised areas are richer and more capable of absorbing goods than poor and backward countries. Yet Britain's trade was then, as it is now, primarily directed elsewhere than to the Continent. Some extraneous factor seems to be involved. Furthermore, the whole argument is based upon the assumption that it would be beneficial to this country to increase its exports and thus maintain its share in world trade. That is an assumption that cannot be accepted without examination. For, in these days, when the Government so earnestly preaches the need to export, it does need to be repeatedly pointed out that a country which exports too freely does not enrich itself but lowers its standard of living. How much does this country really need to export ? The simple answer, of course, is that exports must balance imports ; and there are certain imports that are essential. Since we cannot grow enough at home we must import staple foods. We need to import raw materials, most of which now come from abroad. But because the demand for them will be limited to some extent by the substitution of synthetic materials made from home sources for products mined or grown abroad, the import of raw materials is likely to rise proportionately less rapidly than total home production. We may desire to buy from abroad certain goods not made here and the demand for these goods is likely to rise as standards of living rise. We need capital to invest abroad in order to increase the output of the raw materials our industries need. The amount required is proportional not to total home output but to the rate at which output is increasing. Lastly, certain fixed annual sums are needed to pay the interest upon and pay off the capital of international debts. The conclusions to be reached are that expressed as a proportion of total production at home it is desirable that exports should fall not rise ; and that it is not necessarily relevant to the issue of whether a country is prosperous or not, to study what share its exports play in world trade. It is, however, reasonable to suppose that exports will primarily go to those countries from which predominantly this country imports its food and its raw materials.

It may be, nevertheless, that some increase in Britain's exports to the Continent are desirable particularly when Australia is to make so heavy a cut in imports. For that fraction of this country's imports which consists of goods not made here could conceivably be more completely drawn from Europe than at present. But it seems to us very unreasonable to assume, now that Germany and other Western European countries have recovered from the war, that Britain's share in intra-European trade can be maintained. For much of that trade is merely a reflection of Europe's recovery. It can be compared, indeed, to the great increase there must have been since the war in the movement of civilian goods between Birmingham and surrounding centres such as Cardiff, Bristol, London, Nottingham, Manchester and the North. Were records kept of England's exports to Wales we have no doubt that, as this country recovered from the war, a large increase would have been observed, an increase comparable with the more recent increases of Germany's trade with other Continental countries. We have no doubt either that as the United Kingdom's output rises the figures for the flow of goods across the Welsh marches are continuing correspondingly to rise ! So it is with Germany and its neighbours. Germany's export figures to O.E.E.C. countries reflect the rising output of European industry. But the U.K. can hardly expect a proportionate rise in its exports to the Continent. For primarily those exports must go to countries that provide us with food and raw materials, whereas the Continent is more nearly self-sufficient. It is not, then, the expansion of Germany's trade with other European countries which should bother us. The figures that need watching are those relating to her trade with countries outside Europe. For to those countries we *must* sell in order to buy essential imports. If we cannot compete with Germany on price, delivery, spares, and all those other factors which influence the choice of a purchaser, then, for lack of the raw materials that are exchanged for our goods, our industries will languish whilst those of Germany, for the opposite reason, will prosper. Those figures, showing Germany's trade with primary producing areas increasing very appreciably more rapidly than ours, are much more alarming than are the figures for intra-European trade. Moreover, if we cannot meet German competition in our traditional markets, what hope have we of meeting it in Europe which, broadly, is the home market for German industry ?

A Seven Day Journal

Railway Vehicle and Track Testing Installation

THE British Transport Commission has approved plans for the construction of a vehicle and track testing installation at a cost of about £350,000, between Branston and Wicknor Junction, in Staffordshire. This project, which forms an essential adjunct to the modernisation plan for British Railways, will be the first permanent test plant of its kind in Europe. The objects of the scheme are to enable the compilation of technical information about the performance of different types of locomotives, carriages and wagons over tracks in varying conditions of wear, and at a wide range of speeds. Such information will be of considerable importance in connection with the progressive introduction of diesel and electric equipment under the modernisation plan, and will help to ensure a high standard of safety and comfort resulting from the design and maintenance of vehicles and tracks. The new test installation will comprise nearly 3¾ miles of both straight and curved track. The curves will be used to study the movement of vehicles and their design and behaviour on sharp curves, and to examine the design, layout and maintenance of the tracks themselves. Test lengths of track will enable any particular condition of wear to be artificially created and controlled, and any new kind of track component or equipment to be tested without having to relay a section of line in ordinary use. The installation will enable speeds of up to 60 m.p.h. to be attained over short distances, but higher speed tests will be carried out on suitable lengths of other main lines. The test stretch of line will be laid on the east side of the straight stretch of the Derby–Birmingham main line of the London Midland Region, and it will take about two years to complete. The installation will be operated by the British Railways Research Department, whose main centre is at Derby some 20 miles away, and a further part of the project will be the doubling of the size of this department's laboratories in order to accelerate research in connection with the modernisation plan.

"Unipede" Banquet

DELEGATES to the tenth congress of "Unipede" (the International Union of Producers and Distributors of Electricity) were entertained to a banquet at Grosvenor House, London, on September 22nd by the Central Electricity Authority and the Area Electricity Boards. The toast of the electricity supply industry was ably proposed by Professor H. C. J. Gelissen, of Holland, who spoke of the progress made by the Industry in recent decades and of the ultimate prospect that, when nuclear power was fully developed, coal could be put to its proper use as a valuable source of chemical wealth, rather than power. He also welcomed the possibility of a submarine power cable as a means of drawing Great Britain's economy closer to that of the Continent. In his reply to the toast, Lord Citrine, chairman of the Central Electricity Authority, illustrated the growth of the electricity supply industry in Great Britain by saying that the number of consumers had increased by about 3,000,000 in the seven years since vesting day and by about 5,000,000 since 1939. Affirming his faith in the supply industry and in its ability to meet the needs of an expanding economy, Lord Citrine went on to deplore the fact that the only signs of pessimism were shown by the Government and the banks, who appeared to doubt the ability of the country to finance the new power development schemes. Sir Henry Self, the deputy chairman (administration) of the C.E.A., proposed the toast of the guests and of the many overseas organisations that were collaborating in the congress. Signor P. Ferrario, the retiring president of "Unipede," in his response, expressed the thanks of the guests to the organisers of the congress and, in particular, to Lord Citrine, who, despite his heavy responsibilities as head of the largest organisation of its kind in the world, had found time to preside over the meetings.

List of Centenarian Firms

In a Centenary Number to be issued to mark the Centenary of this journal on January 4th next year there will be included a list of British manufacturing and consulting firms, institutions and societies and journals operating in the fields covered by "The Engineer" which will have celebrated their Centenaries by January 4, 1956. To ensure inclusion in the list each such firm or society in the engineering and allied industries, the iron and steel industry, the shipbuilding industry, and any other industries whose activities are commonly reported in "The Engineer," should inform us about the date of its foundation, its title at that time and its present title, before October 7th next, addressing the communication to The Editor, "The Engineer," 28, Essex Street, London, W.C.2.

Fuel Efficiency

A REFRESHER course for works and plant engineers on the subject of "Current Practice in Fuel Efficiency," is being held this week at Oxford under the auspices of the National Industrial Fuel Efficiency Service. It was opened on Monday by Mr. E. Julian Pode, director of N.I.F.E.S., who suggested that all who preached fuel efficiency laboured under the disadvantage that nuclear energy was "headline news." But for practical purposes, he continued, it was safe to say that, over the next ten to twenty years, coal and oil would continue to be the main sources of industrial power in this country. Future energy requirements could not be calculated precisely, but if past trends continued twenty years hence, the United Kingdom would need the equivalent of at least 300 million tons of coal a year. Until nuclear power came to our rescue, Mr. Pode commented, our fuel supplies were going to be insufficient for our needs. It appeared, he added, that 250 million tons of coal would be this country's ceiling output, and that coal would be a wasting asset which could be won only at increasing cost. Mr. Pode went on to say that from a national and individual standpoint it was imperative that the fuel this country had available was used in the most efficient way possible. When N.I.F.E.S. was formed it was estimated that at least 9,000,000 tons of coal were being wasted each year, and this year's annual report of the Industrial Coal Consumers' Council had put the figure as high as 20,000,000 tons. A survey of 953 plants in the past eleven months, Mr. Pode stated, had shown that 26 per cent of present coal consumption could be saved, to the extent of nearly 300,000 tons a year. The laws of supply and demand would inevitably make fuel more costly than it was now, so that any fuel-saving plant which proved economic on present prices was bound to show additional economies over the life of the plant. Industries whose costs were heavily affected by fuel employed fuel engineers, did research into the problem and usually made the best use of their fuel. Even in the large industries, however, Mr. Pode asserted, sometimes fuel economy installations were not put in because the savings were small in relation to the total annual expenditure of those industries.

Coke Ovens Extended

ON September 22nd, the Minister of Fuel and Power opened an extension of the coke ovens at The Stanton Ironworks Company, Ltd., at Ilkeston, near Nottingham. Mr. A. C. Stewart, the chairman, in his address, mentioned that the new facilities represented an outlay approaching £5,000,000, and explained that blast-furnace gas was cleaned and used to heat the coke ovens, the coke-oven gas being sold to the local Gas Board. He referred to the dependence of the iron and steel industry on coal, as emphasised by the shortage experienced in 1947, and pointed out that while some 40·4 cwt of coal were used per ton of steel produced then, the corresponding figure for the 20,000,000 tons of coal used in 1954 was 35 cwt. The Rt. Hon. Geoffrey Lloyd, M.P., congratulated the industry on this contribution to coal economy, and went on to observe that a valuable feature of the new ovens was that they would accept a proportion of coals of local origin that had not previously been acceptable for steel-making.

Mr. Arthur Watson

WE regret to record the death of Mr. Arthur Watson, the assistant managing director of The Stanton Ironworks Company, Ltd. Mr. Watson, who was sixty-two, died suddenly at Stanton, on Thursday morning of last week, during the opening ceremony of his company's coke oven plant extension, to which reference is made on this page. Arthur Watson was born in Glasgow, was educated at the Glasgow High School and at the Royal Technical College, and in the early part of his professional career, he spent some time with the Summerlee Iron Company. He served in the Royal Artillery throughout the first world war, and shortly after demobilisation in 1919 he began his long association with The Stanton Ironworks Company, Ltd. Mr. Watson's first appointment with the company was in the iron pipe department, and later he became personal assistant to the commercial manager, subsequently taking charge of the foundry sales department. In 1933, Mr. Watson was appointed manager of the iron pipe department, and in 1939 he became commercial manager of the cast iron departments. He was promoted to the office of assistant managing director in July, 1940. He had thus spent more than thirty-five years in the service of the Stanton Company. Mr. Watson was actively associated with the affairs of many trade associations and at the time of his death was chairman of the Cast Iron Segment Association and of the Cast Iron Pipe Association. He was also a past chairman of the Society of British Gas Industries. He was a member of the executive committees of the Joint Iron Council, the Foundry Pig Iron Producers' Association, and the British Slag Federation.

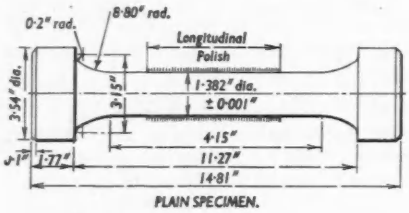
Crack Formation and Stress Concentration Effects in Direct Stress Fatigue

By N. E. FROST, B.Sc.(Eng.), A.M.I.Mech.E.*

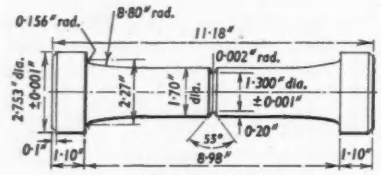
No. I

Reversed direct stress (zero mean load) fatigue tests have been carried out on vee-notched cylindrical specimens of aluminium alloy. Microscopic examination revealed that non-propagating cracks could be formed in the root of the notch. A crack formed grows to a uniform depth and is continuous around the periphery of the notch. It appears that the cracks are fully formed after about 100,000 *cycles. There is a minimum nominal stress below which cracks do not form, but between this value and the nominal stress at the fatigue limit of the notched specimens, non-propagating cracks are always formed. The extent of the penetration of the non-propagating crack depends on the stress field generated by the notch and seems to be equal to the depth of material over which the alternating maximum principal stress is greater than the fatigue limit of the virgin material. The effect of the formation of these non-propagating cracks on the stress-concentration effects of notches is discussed and it is suggested that they lead to the idea of a limiting maximum strength reduction factor. The experimental work described is to be extended to cover a wide variety of notch shapes, materials and loading conditions.*

THE danger of stress-concentration effects has been appreciated for over a century[1] and during this time a large amount of experimental and theoretical work has been devoted to the subject. It is known that plastic strain can reduce stress-concentration effects by causing a redistribution of stresses around the stress raiser, but under fatigue loading it is possible to have the full theoretical elastic stress-concentration effects and for failure to take place with little or no stress redistribution. In practice, even when the stresses involved can cause little or no



PLAIN SPECIMEN.



NOTCHED SPECIMEN.

Fig. 1 and 2—Alloy fatigue specimens for direct stress machine

stress redistribution, the full theoretical factor is not always realised, and this has been the theme of much published work. The conclusions drawn from previous work are :

(*a*) there appears to be a size effect, and

(*b*) the proportion of the theoretical stress-concentration factor realised depends upon the material.

For geometrically similar notches there is a size effect as regards specimen size ; the larger the specimen the nearer the strength reduction factor approaches the theoretical value. For a given size of specimen there appears to be an absolute size effect as regards the discontinuity or notch.

A notch in a hard steel specimen will cause a greater reduction in strength than the same shaped notch in a mild steel specimen. This has led to certain materials being termed " notch-sensitive," while mild steel is referred to as " notch-insensitive." It has been considered that the impact strength of the material should bear some relation to the notched fatigue strength, but Gough[2] has shown that the Izod value bears no relation to the fatigue strength of either plain or notched specimens.

The ratio of the fatigue strength of a plain specimen to a notched specimen of the same material is called the " strength reduction factor " or "the effective stress-concentration factor," and is usually designated β_k. If α_k is the theoretical elastic stress-concentration factor, the quotient $(\beta_k-1)/(\alpha_k-1)=n_k$ is referred to as the notch sensitivity index of the material. It was hoped that this method would allow problems relating to notches to be solved as n_k was supposed to be a constant of the material, but the problem of the notch or discontinuity in a fatigue specimen cannot be solved in this simple manner.

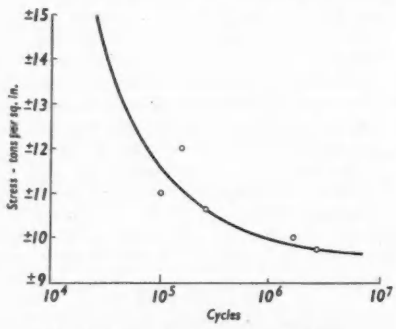


Fig. 3—S/N curve for plain specimens

There have been two approaches to the problem of the propagation or growth of a fatigue crack. The first was that once a crack had formed it would propagate rapidly, due to the supposedly high stress-concentration set up at the tip of the crack. The second as mentioned by Head[3] that a crack could form at as early as 10 per cent of the estimated life and then spend the remaining 90 per cent in propagating.

In this article the problem is considered in the light of work done by Phillips and his co-authors.[4, 5] Fenner, Owen and Phillips[4] showed that for a mild steel specimen containing a sharp vee-notch, fatigue cracks could be formed at low nominal stresses in as few as 50,000 loading cycles and that no growth of the crack occurred even up to endurances of 100 million cycles. The nature and conditions governing the initiation and propagation of fatigue cracks are discussed, and it is shown that non-propagating cracks formed in notched fatigue specimens lead to the idea of a limiting maximum strength reduction factor which cannot be exceeded for any material irrespective of the type of discontinuity introduced.

Experimental Details

The purpose of the experimental work was to test specimens containing a stress raiser under reversed direct-stress fatigue loading, and to investigate the formation and propagation of cracks, if any, set up by the stress raiser. The shape of the specimen and stress raiser were identical with those used by Phillips[4, 5] for tests on steels, so that his results could be incorporated in this article.

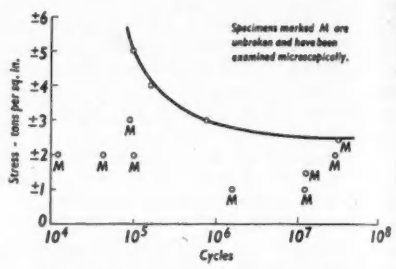


Fig. 4—S/N curve for notched specimens

As mild steel had been used for the previous work on crack formation, it was decided to use a relatively brittle engineering material for contrast. In the present investigation, an aluminium alloy conforming to British Standard L 65 was used. The nominal chemical composition and mechanical properties are :

Chemical composition, Cu 4·4 per cent, Mg 0·7 per cent, Si 0·7 per cent, Mn 0·6 per cent.

0·1 per cent proof stress, 28 tons per square inch minimum.

Ultimate tensile stress, 32 tons per square inch minimum.

Elongation on $4\sqrt{\text{area}}$, 8 per cent minimum.

The material was used in the fully heat-treated condition, i.e. solution treated at 505 deg C, water-quenched, and aged at 160 deg. to 190 deg. C.

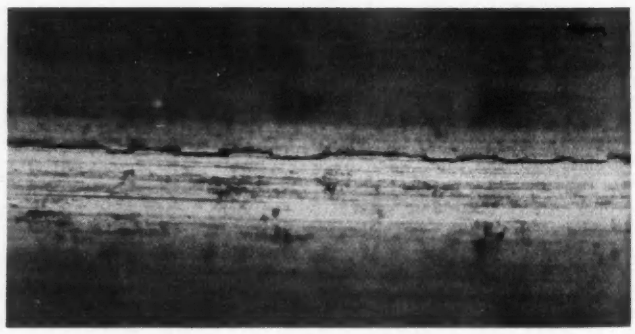
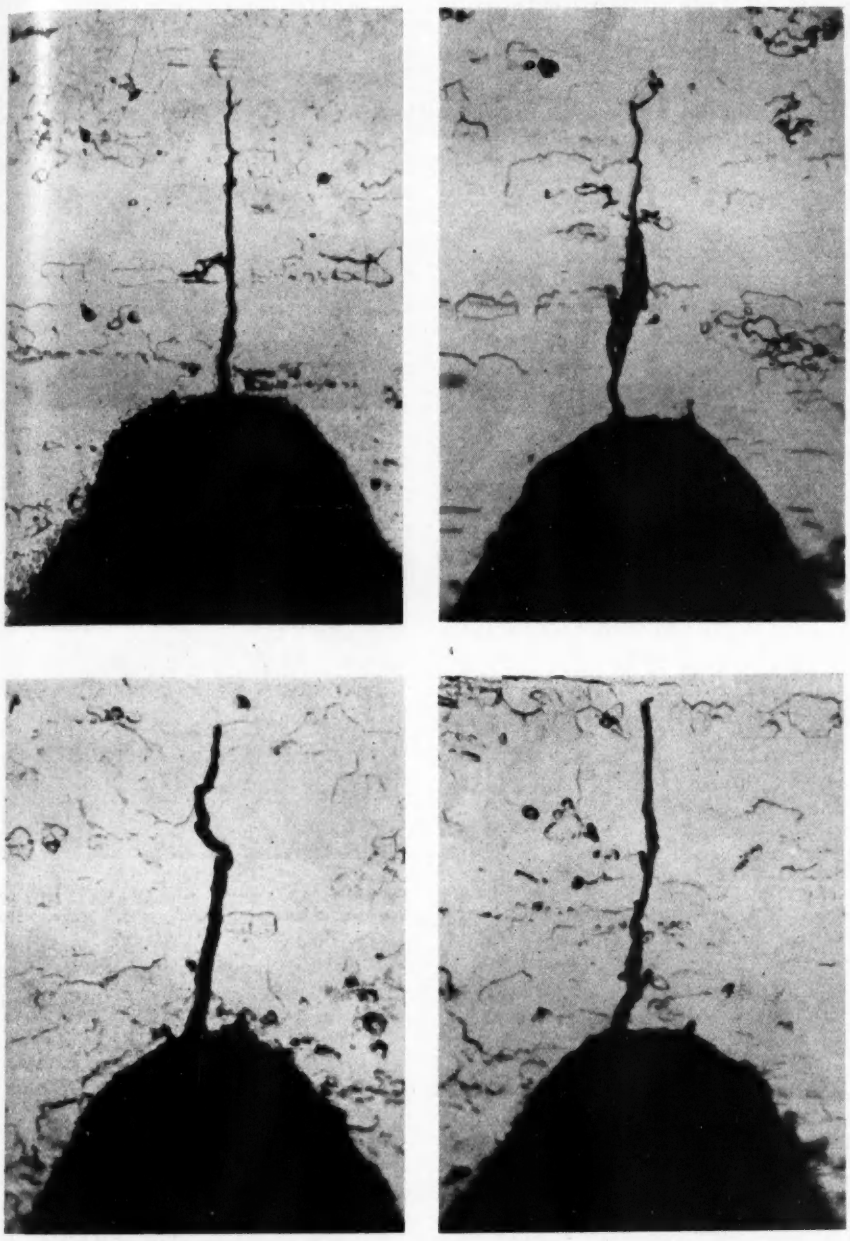


Fig. 5—Surface crack at root of notch specimen MBCG 14C. ±2 tons per square inch, 99,000 cycles. Magn. ×200

Reversed direct-stress fatigue tests were carried out on notched and plain specimens. Fig. 1. gives the dimensions of the plain specimen and Fig. 2 those for the notched

* Mechanical Engineering Research Laboratory, East Kilbride, Glasgow.



Figs. 6, 7, 8 and 9—Cracks in specimen MBCG 14M. ± 2 tons per square inch, 28,047,205 cycles. Magn. ×500

specimen. The notch has a root radius of 0·002in and great care was exercised in the machining so that it was the same for all specimens. The consistent accuracy of the notches is clearly shown in Figs. 6–22.

All the fatigue tests were carried out in a 60-ton Schenck pulsator at zero mean stress. Unless otherwise stated, all stresses referring to the notched specimens are nominal stresses based on the minimum diameter of the specimen.

TABLE I—*Details of Fatigue Tests on Notched Specimens*

Specimen mark	Applied nominal stress	Cycles	Remarks
	Tons/sq. in		
MBCG 14H	±5	99,813	Broken
MBCG 14N	±4	150,500	Broken
MBCG 14E	±3	671,947	Broken
MBCG 14M	±2	28,047,250	Unbroken
MBCG 14C	±2	99,000	Unbroken
MBCG 14D	±2	11,500	Unbroken
MBCG 14G	±2	49,500	Unbroken
MBCG 12L	±1	1,594,500	Unbroken
MBCG 1H	±1	12,402,000	Unbroken
MBCG 1G	±1½	13,570,000	Unbroken
MBCG 14L	±2½	31,054,200	Unbroken
MBCG 14J	±3	95,700	Unbroken
MBCG 12K	0	0	Unbroken

All specimens noted as unbroken were subject to microscopic examination.

EXPERIMENTAL RESULTS

The plain specimens were tested first to obtain the normal S/N curve, shown in Fig. 3. With the notched specimens, preliminary tests to fracture were made to obtain the S/N curve shown in Fig. 4. Further specimens were tested at stresses below the notched fatigue limit for varying endurances and then removed from the fatigue machine and examined under the microscope. Specimens examined microscopically are marked with an *M* in Fig. 4. Table I gives details of the tests on the notched specimens.

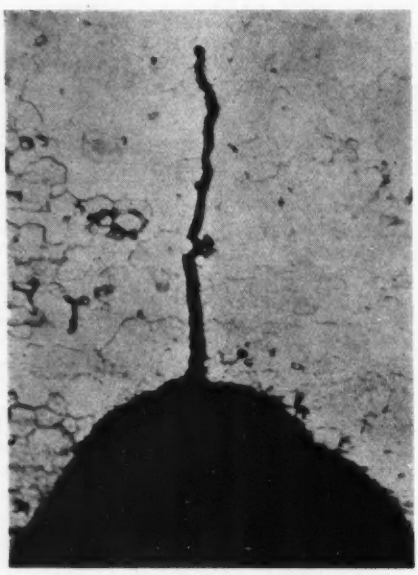
Figs. 3 and 4 show that the fatigue limit in direct alternating stress of the plain specimens was ±9·75 tons per square inch, and the fatigue limit of the notched specimens ±2·5 tons per square inch ; this gives a strength reduction factor for the notch of 3·9.

MICROSCOPIC EXAMINATION

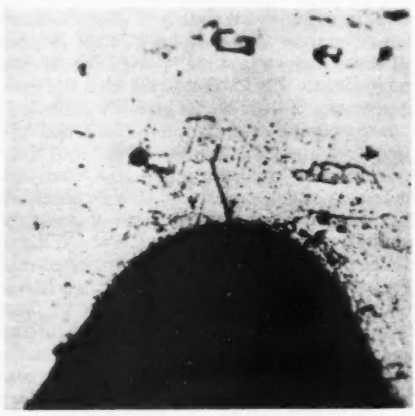
After a specimen had been tested the outside diameter was turned down carefully until the notch depth had been reduced to about 0·02in. The centre ½in containing the notch was then machined from the specimen so that a cylinder ½in wide by 1·34in diameter was obtained. The periphery of the bottom of the notch was then viewed under the microscope. Fig. 5 shows the characteristic appearance of a crack. Where it was obvious that the crack was continuous around the periphery the cylinder was machined into four quarters by splitting across two diameters at right angles. If it was uncertain that a crack was present (and it must be emphasised that in some cases it was difficult to decide whether a crack was present or not) a selective slice was taken and the two halves again split. Hence there were four faces taken at 90 deg. intervals around the circumference of the notch suitable for viewing under the microscope. Each section was mounted, polished and etched using Keller's reagent. If the fatigue cracks had the same general characteristics on all four quarters it was assumed that the crack was of even depth around the periphery. A typical example, Figs. 6, 7, 8, 9, shows the uniformity of the crack produced ; this also indicates the high degree of axiality of loading obtained with the Schenck fatigue testing machine.

TABLE II—*Details of Specimens Examined Microscopically and Values of Crack Depths*

Specimen mark	Stress, tons/sq. in	Cycles	Sections photographed	Fig. No. of photograph	Crack depth, inches	Remarks
MBCG 14M... ...	±2	28,047,250	1 2 3 4	6 7 8 9	0·0044	Crack depth uniform on all four sections examined Indication of formation of small secondary crack
MBCG 14C	±2	99,000	Surface 3 1 4	5 10 11	0·0044	Crack depth uniform in all four sections examined Small secondary crack formed on some sections
MBCG 14G... ...	±2	49,500	1 3	12 13	0·0010	Crack completely around periphery, but uneven in depth. Depth given is maximum depth found as shown on Fig. 12. Secondary crack present in some sections
MBCG 14D... ...	±2	11,500	1 3	16 17	0·0010	Crack depth uniform in all four sections. Secondary crack formed on some sections
MBCG 12L	±1	1,594,500	—	—	0	No trace of a crack could be detected
MBCG 1H	±1	12,402,000	—	—	0	No trace of a crack could be detected
MBCG 1G	±1½	13,570,000	4 2	18 19	0·0018	Crack depth uneven. This specimen was the only one in which crack has not grown perpendicular to applied stress. Depth given is maximum value found
MBCG 14L	±2½	31,054,200	2 4	14 15	0·0059	Crack depth uniform on all four sections examined
MBCG 14J	±3	95,700	2 1	20 21	0·0075	Crack depth very uneven due to non-axiality of load once crack had started to propagate. Depth given is rough average of initial depths obtained on the four sections
MBCG 12K... ...	0	0	2	22	0	"Unrun" specimen sectioned to check machining

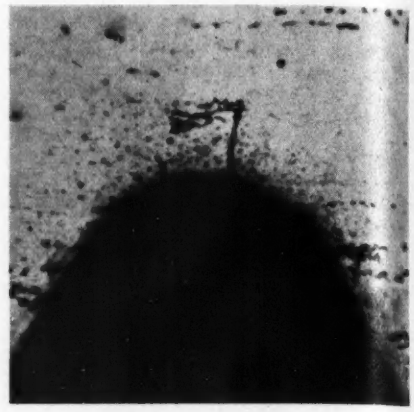


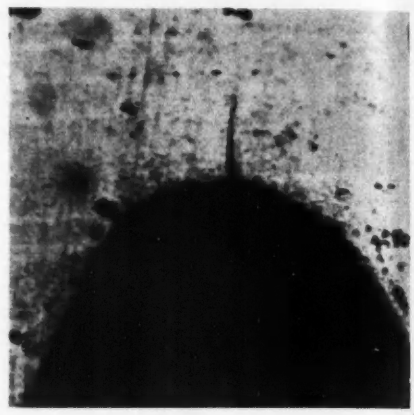
Figs. 10 and 11—Crack in specimen MBCG 14C. ±2 tons per square inch, 99,000 cycles. Magn. ×500



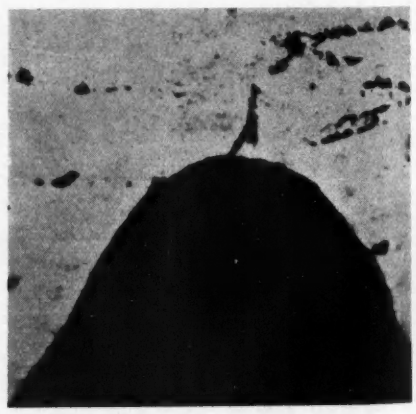
Figs. 12 and 13—Crack in specimen MBCG 14G. ±2 tons per square inch, 49,500 cycles. Magn. ×500

Figs. 14 and 15—Crack in specimen MBCG 14L. ±2½ tons per square inch, 31,054,000 cycles. Magn. ×500

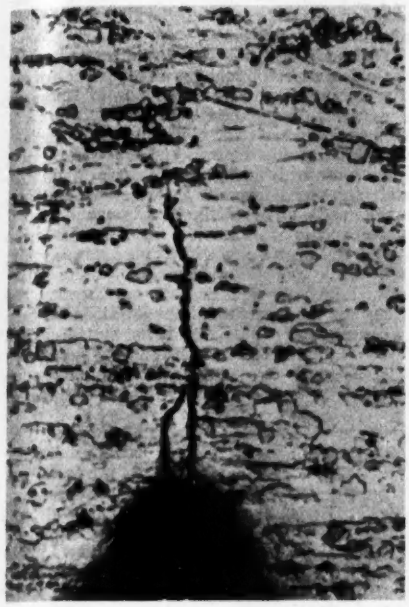




Figs. 16 and 17—Crack in specimen MBCG 14D. ±2 tons per square inch, 11,500 cycles. Magn. ×500



Figs. 18 and 19—Crack in specimen MBCG 1G. ±1½ tons per square inch, 13,570,000 cycles. Magn. ×500



Figs. 20 and 21—Crack in specimen MBCG 14J. ±3 tons per square inch, 95,700 cycles. Magn. ×200

Fig. 22—"Unrun" specimen MBCG 12K. Magn. ×500

In those few specimens where the fatigue crack was not so uniform specimens were repeatedly ground and polished so that the general pattern of the growth of the crack could be obtained. Results of the microscopic examinations are given in Table II.

Discussion of Fatigue Cracks Formed in Notched Specimens

Figs. 6, 7, 8, and 9 show the crack formed after running for 30×10^6 cycles at a stress of ±2 tons per square inch. On Figs. 7, 8, and 9 there is an indication that a second crack has begun, but the main crack has predominated. There can be no doubt that the crack has formed evenly around the whole periphery and has spread to a uniform depth. The cracks do not appear to favour growing along grain boundaries, but pass straight through grain and boundaries indiscriminately. The end of the crack, which appears quite definite, does not seem to be influenced by the grain boundaries. The direction of the growth is at right angles to the direction of the applied stress. For this specimen the maximum depth given in Table II has been taken as the average length of the four cracks shown in the illustrations.

Three other tests were run at ±2 tons per square inch, each for a different endurance. Figs. 10 and 11 are representative of the crack formed after running for 100,000 cycles. Again, the crack had grown to a uniform depth around the periphery and its characteristics were very similar to those of the previous specimen. The estimated depth is the average of the four selected sections. Figs. 12 and 13 show the crack obtained after running for 50,000 cycles. The crack formed was much smaller than that in the two previous specimens, but there was no doubt that the crack extended around the whole periphery even though its depth was not quite so uniform. Figs. 16 and 17 show the crack formed after running for only 11,500 cycles; its characteristics are similar to those of the 50,000-cycles crack. At some parts of the periphery two cracks had formed, but generally, in this case, the longer of the two cracks was of the same length as the crack formed when only one crack was present. The depths given in Table II for these specimens examined are the average of all sections, the longer length being taken when two cracks were present.

Two tests were run at ±1 ton per square inch, the first for 1,500,000 cycles and the second for 12,500,000 cycles. In neither case could any trace of a crack be detected.

Figs. 18 and 19 show the characteristics of the crack formed at a stress of ±1½ tons per square inch after 13·6 million cycles. The crack was continuous around the periphery, but was not particularly uniform in depth. As shown in Fig. 18, the crack had grown at an inclined angle to the usual direction on several of the sections examined, but on others, as shown in Fig. 19, it had grown in the usual direction. The assessed depth is based on the actual lengths of all the cracks measured in the sections irrespective of the angle the crack made with the direction of the applied stress. Figs. 14 and 15 are representative of the crack formed after 31,000,000 cycles at a stress of ±2½ tons per square inch. Here the crack was continuous and had grown to a uniform depth on all sections examined; the growth direction was again perpendicular to the direction of the applied stress. The assessed depth is the average length of the crack on the four sections examined.

Figs. 20 and 21 show the cracks obtained in a specimen after 100,000 cycles at ±3 tons per square inch. It should be noted that the magnification of these two illustrations is ×200 while all the others are ×500. The crack is again continuous around the periphery and perpendicular to the direction of the applied stress, but the depth varies rather considerably. Multiple cracks can also be seen in the root of the notch. The value of the assessed depth given in Table II can only be considered as a rough approximation as mentioned later.

An untested specimen was sectioned to see whether the machining of the notch had caused any cracking at the root. Fig. 22 is representative of the four sections examined and shows no indication of any cracks due to machining. This was confirmed by the two tests run at ±1 ton per square inch in which no cracks were detected. Incidentally, Fig. 22 illustrates clearly the degree of accuracy to which the notches were machined.

References

[1] W. J. Macquorn Rankine, *Proc. Inst. Civil Eng.*, 1843, Vol. 2, page 105.

[2] H. J. Gough, Aeronautical Research Council R. and M. 2522. H.M. Stationery Office, 1951.

[3] A. K. Head, *Phil. Mag.*, 1953, Vol. 44, page 925.

[4] A. J. Fenner, N. B. Owen, and C. E. Phillips, *Engineering*, 1951, Vol. 171, page 637.

[5] C. E. Phillips and R. B. Heywood, *Proc. I.Mech.E.*, 1951, Vol. 165, page 113 (W.E.P. No. 65).

(*To be continued*)

Regulations for the Electrical Equipment of Buildings

The thirteenth edition of the *Wiring Regulations* of the Institution of Electrical Engineers has now been published; it supersedes as from September 1, 1955, the twelfth edition (as amended by the 1954 Supplement). The new edition is in two parts. Part I is based on those requirements which, if not complied with in a consumer's installation in Great Britain, would place the supply undertaking in the position of not being compelled to start or, in certain circumstances, to continue to give, a supply of energy to that consumer. Part II sets out in detail methods and practices by which the requirements of Part I can be met; these methods do not necessarily represent the only means of compliance, but any departure therefrom claiming to meet the essential requirements of Part I would need to be the subject of special consideration. During the drafting of the thirteenth edition, liaison with the Central Electricity Authority and Area Electricity Boards, to whom the regulations are of special importance, was maintained and strengthened, and the new edition should assist the work of the National Inspection Council which has now been set up.

Like its predecessors, the new edition is intended to ensure safety from fire and shock in the installations to which it relates. It represents a measure of simplification as well as a thorough revision of the twelfth edition, and takes into account comments received from interested sources and proved advances in installation techniques. It includes the provisions of the 1954 supplement to the twelfth edition, which was prepared in the light of the revision of B.S. 7: "Rubber-Insulated Cables and Flexible Cords," and the issue of B.S. 2004: "P.V.C.-Insulated Cables and Flexible Cords"; and a detailed review of cable ratings has been carried out in consultation with the Electrical Research Association and Cable Makers' Association. With the publication of the thirteenth edition, the *Temporary Relaxation*, 1952, dealing with the ratings of certain cables, and the *Abridged Wiring Regulations*, issued for the first time on November 15, 1951, are withdrawn. No action will be taken for the preparation of a revised abridged version until experience has shown whether the greater conciseness of the new edition has removed the need. Copies can be obtained from the Secretary, the Institution of Electrical Engineers, Savoy Place, London, W.C.2, at the following prices (post free):—Bound in paper, 6s.; bound in cloth, 8s. 6d.

The Steam Locomotive: A Machine of Precision*

By K. J. COOK, O.B.E., M.I.Mech.E., M.I.Loco.E.†

THE technique of constructing and maintaining steam locomotives on British Railways is now at the summit of accuracy, and if and when the steam locomotive fades away in this country it will not be on account of any decline in the excellence of its mechanism.

A number of factors have combined to bring a point in the history of this country at which the steam locomotive must decline. In the decade which was closing in 1939, there is no doubt that the British steam locomotive was in its ascendancy, and able to hold its own generally against other forms of prime movers on economic as well as mechanical grounds. There were plentiful supplies of large coal, shed maintenance was at its best and continuity of railway employment was attractive. Now there are counter attractions in the form of a short regular working week in lighter industries, a dearth of large coal, and there is no longer a fear of shortage of oil in case of emergency. Nevertheless, the supercession of steam in Great Britain will take a number of years.

The basic mechanism of an orthodox locomotive is unique in that its power is transmitted equally through two, three or more axes whose centres are partly fixed, but are subject to considerable movement relative to their locations and to each other. Concentrated power is transmitted between the axes by rigid couplings subject to rotating and alternating tensional and compressive forces. These movements, caused from within the locomotive by its direct or induced forces and from without by irregularities of the track, have an effect upon the dimensions between axis centres, and argument may therefore develop as to whether extreme basic accuracy is necessary. It is true that if there are errors in original setting, the movement of axes during motion and power transmission may tend to cancel them out, but they may equally add to the error and also to the stresses set up. It is therefore fairly clear that the greater the original accuracy the lower will be the maximum stresses set up in components, and it also enables initial tolerances of working parts to be reduced to a minimum, which in itself reduces hammering effects in bearings and the rate at which wear and slackness develop.

* Presidential address to the Institution of Locomotive Engineers, September 21, 1955. Abstracted.

† Chief Mechanical and Electrical Engineer, Eastern and North Eastern Regions, British Railways, Doncaster.

I would like now to emphasise that the above remarks apply to certain parts of the locomotive and not necessarily to each and every part. In general, it is probably correct to say that the more accurately centres of holes are maintained the better, but there are some components in which very close tolerances are detrimental and therefore a proper balance is necessary. But on the basic components of power transmission in a locomotive, and in many other parts, a high degree of accuracy is highly desirable and economical. We should probably all agree that the economical criterion of locomotive performance is cost per mile in similar conditions of operation and one of the greatest factors in producing a low cost per mile is mileage obtained between heavy repairs. In carrying out a heavy repair, the dismantling and erecting costs are fairly constant, whatever the mileage, and a higher mileage enables these to be spread and to produce a lower overall figure. High precision in basic details of a locomotive can make a big contribution to economy.

There are two ingredients in the production of accuracy in a locomotive mechanism, viz., measurement and working to measurement. Measurement has to cater for three-dimensional requirements over an extensive area and many years have been needed to arrive at the present possibilities. Each works has to cater for a number of combinations of these dimensions within the overall maxima and hence any system must be flexible enough to cater for these at reasonable cost and facility.

In the first place there are the cylinder centre lines throughout the length of the engine with the axle centres to be located at right angles and at correct distance from cylinder barrels. For many years methods remained fairly uniform, using simple apparatus in the form of fine cord or wire stretched from front cylinder faces to rear of engine, set by calipers from front and back of cylinders, meeting a straight edge clamped on supports in the centres of the driving horns. The supports incorporated fixed or movable centres from which checks fore and aft to similar centres in adjacent axlebox guides could be made by trammels, either solid or adjustable. Check for normality of axis to cylinder line was by large steel squares and for parallelism of framing and horn edges to centre line by steel rule. Should right angles of axis not be proved, the lines had to be removed, adjustments to surfaces made and the lines and straight edge reset for checking.

There was a good amount of subterfuge in the olden days for making lines appear to run true and in subsequent machining of components it was generally assumed that wear or inaccuracies were equal on each side of engine. Nevertheless, with good craftsmen working under favourable conditions fairly good results were obtainable, and high-speed locomotives were repaired and maintained on these methods, although in general at the expense of slack initial fits of some wearing parts. But when things did not proceed according to schedule, poor light, blunt pops and a short-sighted erector, considerable inaccuracies did occur and many engineers have spent much time in endeavouring to develop better systems. The road was difficult and much time was spent with little progress until optical methods became available and opened up the way for advances in direct measurement.

The general term of "frame alignment" used in connection with optical methods rather camouflages the main quest. More important is the setting of horn centres relative to each other, together with length of coupling rods and throw and angle of crankpins. Nevertheless, it will be shown that following on this a complete alignment throughout of wheels relative to framing is achieved.

The first major step was due to a well-known German optical instrument maker who, in the late 1920s, produced a telescope in conjunction with a collimator. The telescope, of course, enabled a sight to be taken free of all deflection and the function of the collimator was to pick this sight up on absolute parallelism.

The cross lines of the infinite scale of the collimator will only register zero from the telescope if the former is correctly located parallel in the line of sight. Hence if this be suitably and accurately mounted at right angles to a straight edge or tube supported horizontally in the driving horns, at the designed distance from locating point on the cylinder, an axis has been set up co-incident with the desired centre of driving axle. In this application, the collimator is clamped in vee blocks accurately set at right angles to a cross tube, mounted on a stand having means of easy adjustment in all directions. The cross tube accommodates a micrometer carrier by which measurements can be taken to front and back guide faces and also to adjustable measuring studs from which, by suitable measuring rods, centres in adjacent guides can be set up.

By this means, an accurate survey of all horn faces relative to cylinders at commencement of repair can be made and decision taken as to the most economical directions for correction. With optical systems, it is usual to work from the

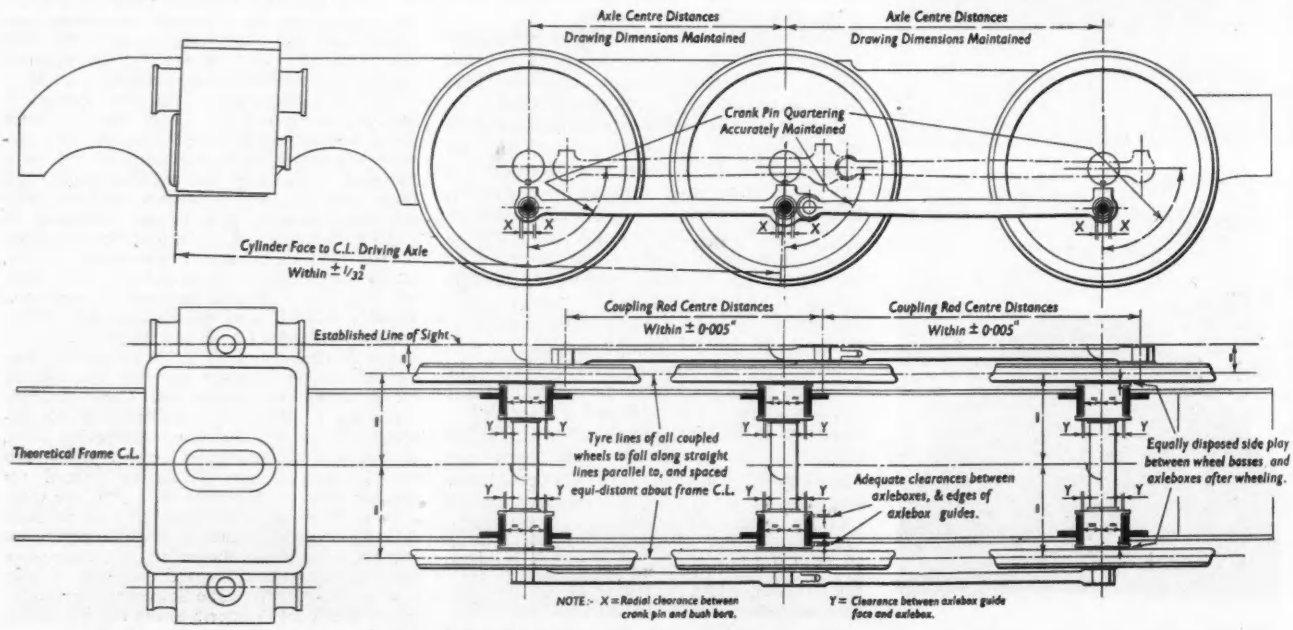

Axle Centre Distances
Drawing Dimensions Maintained
Axle Centre Distances
Drawing Dimensions Maintained
Crank Pin Quartering
Accurately Maintained
Cylinder Face to C.L. Driving Axle
Within ± 1/32"
Coupling Rod Centre Distances
Within ± 0·005"
Coupling Rod Centre Distances
Within ± 0·005"
Established Line of Sight
Theoretical Frame C.L.
Tyre lines of all coupled wheels to fall along straight lines parallel to, and spaced equi-distant about frame C.L.
Adequate clearances between axleboxes, & edges of axlebox guides.
Equally disposed side play between wheel bosses and axleboxes after wheeling.
NOTE:- X = Radial clearance between crank pin and bush bore.
Y = Clearance between axlebox guide face and axlebox.

Fig. 1—Essential requirements of a locomotive alignment system

front cylinder face setting the location point of the telescope flush with it. At the rear end of the telescope tube there is an anvil from which the measuring rod to collimator cross tube is set up. Under this system an attachment holding a dial indicator is mounted at one end of all measuring rods and the rods are such that the designed length is shown when the dial indicates 200 (graduated in thousandths of an inch), and the length gauges allow where applicable for the 4in dead length of the adjustable measuring studs. The telescope can also sight on to scales fixed to each horn face or frame at any point and coincidence with or divergence from the designed measurements be ascertained.

The telescope is a compound appliance, having the telescope proper mounted within the telescope tube which can swivel horizontally within the outer tube. It is not unusual—in fact it is usual—for there to be a slight misalignment between cylinder bore and the theoretical centre line. Within limits there is no need to correct this and by setting the telescope proper to the established line of sight the theoretical line is set up and from this all dimensions can be obtained to enable the wheels to be correctly positioned throughout the engine in their correct operating position relative to frame and rail.

Having surveyed the frame and taken all necessary measurements, it can be decided exactly the amount to be taken off or added to each axle-box guide face. There can be a small amount of give and take in the length cylinder face to driving box guides provided the cylinder clearance is maintained and by using this one way or another, the minimum amount can be specified to be removed from each axlebox guide face to bring axle centres correct. In the fixing of these amounts, in thousandths of an inch there need be no tolerances, but the other ingredient comes in in the form of how accurately the corrections can be made. The method par excellence, is a fixed grinder with rigid bed and grinding heads, which can produce accurate plane surfaces. Such a machine however, is expensive and the layout of some erecting shops does not lend itself to facilitate the convergence of all frames at the one location of the grinding machine. Accuracy within two or three thousands can, however, be produced reasonably quickly by the use of portable grinding machines and surface plate, entailing a greater demand on human effort. There are two forms of portable hand grinding machine, one using a cylindrical abrasive wheel and the other a cup wheel, an adaptation of a portable cup wheel grinder into a semi-fixed machine. Having a hand operated oscillatory wheel traverse this machine can be set at various points along a prepared floor to suit all horns.

Such equipment was installed in about twenty-five German railway works and one works in Great Britain. At the Machine Tool Exhibition of 1952, a British optical exhibit was noticed which appeared to be capable of development although at that time it had no reference to locomotives. The makers became very anxious to co-operate and quite quickly a method much simpler than the German, and capable of proceeding very much further in the quest for accuracy, was produced. It became known as the Auto-Reflection method, utilising instead of a collimator a reflecting mirror fixed parallel to and in line with a straight edge. The auxiliary apparatus and measuring rods also are much simpler. The 2in front silvered mirror is mounted on a carrier so that the mirror face is parallel to and in line with the rear edge of a straight edge set between the driving horns. Fig. 3 shows the telescope sighting on to the mirror under conditions in which the straight edge has an angular displacement and it also shows the view through the eyepiece of the telescope which in the present case gives a reading of 115. This reading when divided by the distance between the end of the telescope and mirror face (in feet) is the angular error in thousandths of an inch per foot. On the carrier also the measuring anvils facing fore and aft, in line with mirror and straight edge, with measuring bar supports are shown.

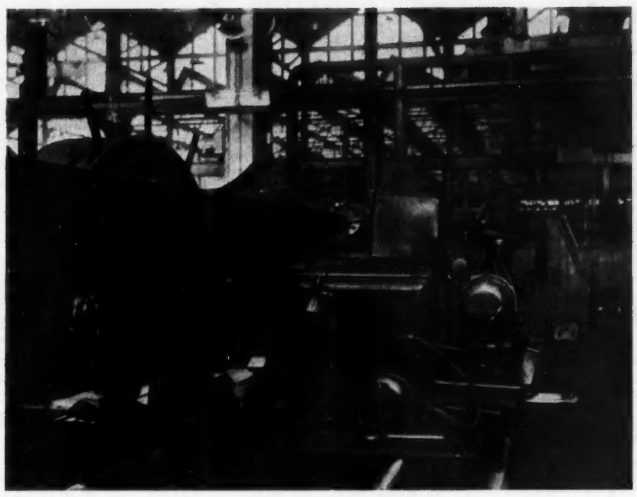


Fig. 2—Horn grinding machine

The telescope unit is approximately 18in long and weighs 10 lb. The main part of the body is 2¼in diameter, hardened and precision ground to an accuracy of 0·0003in cylindrical and parallel within 0·0002in. It is ideally suited for mounting in a self-centring fixture in a locomotive cylinder for outside application or in an adjustable bracket for inside cylinder application. The lens system is totally enclosed within the body and is of the internal focusing type. Rotation of the focal control provides for objects as close as 20in or as far as 150ft from the end of the telescope to be brought into focus in the plane of the cross-wire graticule.

The telescope holder and adaptor consists fundamentally of two tubes, the inner one, which accepts the telescope itself being concentric with the outer one when the adjusting dial is at zero. The outer tube is self-centring at the rear end in the cylinder stuffing-box and at the front in the cylinder mouth, by three cam-operated locating pins which have steps machined on them near their tips. When these tips abut on the front cylinder face, the anvil at the rear end of the adaptor becomes a zero for measurement from cylinder centre. The outer tube carries a pedestal to accommodate a spirit level for horizontal setting, which is important for ascertaining angular displacement.

The front end of the telescope is provided with a cover glass upon which is marked a circular pattern target. The circles are numbered to a suitable scale and are concentric with the body diameter. These circles are not visible when observing forward through the eyepiece as the main lens system is at all times focused at a distance beyond the cover glass. An illumination system within the telescope provides light for projecting the image of the circles forward from the end of the tube. The telescope optics ensure that the image of these circles travel in line parallel and coaxial within the telescope line of sight.

To reflect the target graticule circles back into the telescope the 2in diameter silvered mirror is placed in the telescope line of sight. The reflected image is viewed in the telescope with respect to the internal cross-lines. The overall magnification of the lens system is 30, thus making $^{1}/_{64}$in reading on a steel scale possible over long distance. It is possible to measure displacement of objects or targets in relation to the line of sight of the telescope to accuracies of 0·004in at 100ft and proportionately for longer or shorter distances. The accuracy of squareness settings becomes greater as the distance between telescope and mirror increases. Settings can be made to an accuracy of eight seconds of arc with the mirror 1ft away from the telescope and to half a second, at a distance of 25ft. Readings can be at distances of 150ft.

It was considered at the outset that the essential requirements of a satisfactory locomotive frame alignment system should embrace the following features :—

(1) It should be universally applicable to all classes of locomotives.

(2) Axlebox guide faces should be equidistant about axle centre-line and axleboxes bored centrally.

(3) Axle centre lines should be parallel to each other and at right angles to the established frame centre line.

(4) Horizontal centre distances of coupled wheels should be maintained to drawing dimensions within limits specified.

(5) Driving axle distance from cylinder centre should be maintained to drawing dimension.

(6) Tyre line of all wheels should fall along straight lines parallel to the established frame centre line and spaced equidistant about it.

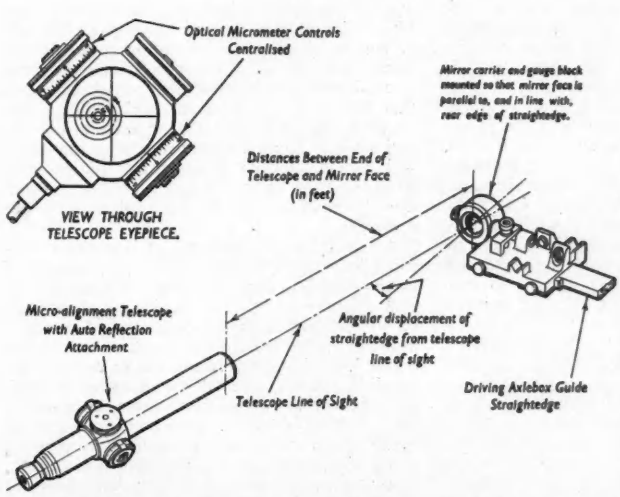

Optical Micrometer Controls Centralised
Mirror carrier and gauge block mounted so that mirror face is parallel to, and in line with, rear edge of straightedge.
Distances Between End of Telescope and Mirror Face (in feet)
VIEW THROUGH TELESCOPE EYEPIECE.
Micro-alignment Telescope with Auto Reflection Attachment
Angular displacement of straightedge from telescope line of sight
Telescope Line of Sight
Driving Axlebox Guide Straightedge

Fig. 3—Checking squareness by the auto-reflection method of optical alignment

These are illustrated in diagrammatic form in Fig. 4, applied to an outside cylinder engine. The telescope is set up in one of the cylinders sighting on to the mirror which is reflecting the rays back to give a zero reading. An enlarged view outside shows the mirror attached to straight edge and on the mirror carrier three gauging anvils, with length bars in position, the outside one being an adjustable one for length from the front cylinder face with one fore and one aft to adjacent horns. On the left-hand side is an adjustable straight-edge for use in checking parallelism of horn faces. Width of horn gaps need not be equal even for the opposite position, but condition No. 2 can still be met. Above is the frame width and overall guide edge with gauge. Further to the right is the gauge block for measuring to axlebox guide faces and, lastly, the magnetic rule carrier for measuring from line of sight to horn edge or frame.

The apparatus is fully usable in the construc-

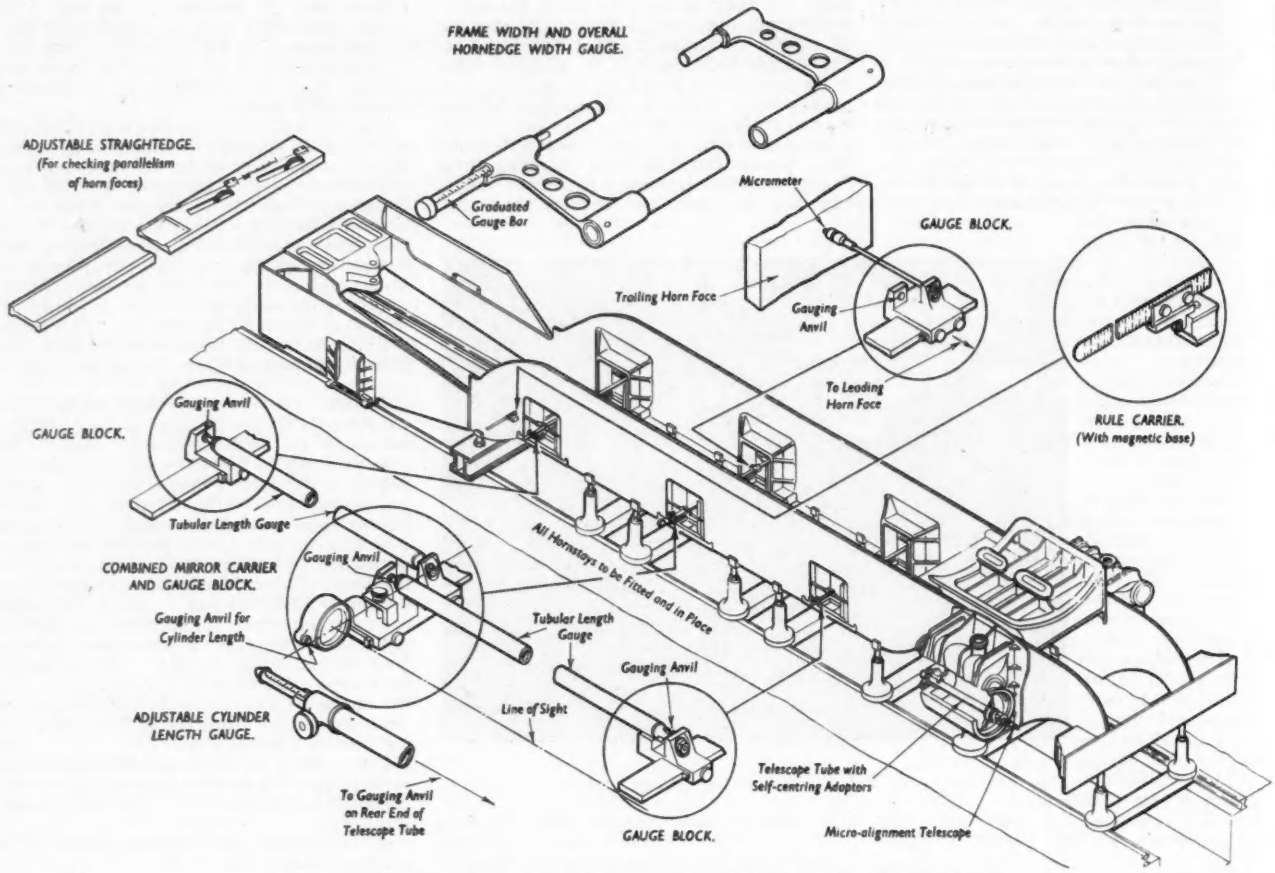


Fig. 4—Optical locomotive frame alignment system applied to an outside cylinder engine

tion of locomotives to ensure initial accuracy. In railway shops the predominating use is in connection with general repairs to ensure and maintain accuracy over a long working life and it is primarily this aspect with which the illustrations and descriptions deal.

Having set up straight edges throughout the axles in their correct position, a direct measurement is obtained at a point on each guide face of the exact amount by which each face should be corrected. The measuring rods and straight edges can then be moved and the telescope used, in conjunction with the overall gauges, to obtain the dimensions to which axlebox flanges must be machined to ensure that the frame will lie naturally relative to the tyre treads.

The telescope establishes a line of sight parallel to the absolute centre line of the engine at a distance of half the cylinder centres from it. First variation of axlebox guide edges (both outer edges of each pair) must show the same final distance from established sighting line. This, in connection with the overall width gauge, establishes deviation from standard and by ascertaining wheel boss position relative to tyre flange, in conjunction with overall distance between bosses after machining, the final required dimension is obtained.

Crank Pins

A component on which it has proved difficult to ensure accuracy is the set of crank pins, three, four of five pairs, as the case may be, affecting the tolerances which can be worked to on coupling rod bushes. Not only is it difficult to ensure accuracy of machining, but again so is the matter of measurement, which is desirable particularly as a check of the continuing accuracy of quartering machines.

The development of the present gauge arose out of a paper on " Metrology " by a member of the National Physical Laboratory given to one of the junior engineering societies, wherein for three-dimensional measurements in different planes the use of spirit levels was indicated, and particularly the great potentialities in this direction of spirit levels of extreme sensitivity. Hence it was felt that a quartering gauge mounting two spirit levels set at 90 deg. would give the basis of a gauge for checking crank pins designed for this angle.

The spirit level tubes in view have a radius of arc, along which the bubble moves, of 1000in and result in terms of locomotive requirements of a movement of the bubble of a tenth of an inch to indicate an angular error of one thousandth of an inch at a radius of 1ft. A slightly different scale of graduations will apply to the usual run of crank pin throws which vary between 10in and 15in. The *modus operandi* is to place the vee on one crank pin and the sliding centre in the axle centre and pinch the wheels until the cross level shows zero displacement which indicates that this pin is at bottom dead centre. The gauge is then taken to the opposite crank pin and similarly applied when any error in angularity will be indicated by displacement of the level lying along the body of the gauge, the error being directly readable from the graduation if it is not too great.

A considerable amount of ingenuity was expended before the measurement of length of throw reached its present form. Originally the sliding centre had vernier markings, which were set in conjunction with a crank pin of standard dimension. Finally a micrometer was incorporated, reading from crank pin to an anvil on the sliding centre, and half the diameter of crank pin taken by an outside micrometer being added. The addition of a third spirit level extended the range of the instrument to cover crank pins set at 120 deg. and in its present form it is capable of measuring the angular setting and throw of crank pins of all normal two, three or four-cylinder locomotives with strokes varying from 20in to 30in. The bubble length is sensitive to changes of temperature, hence a cursor controlled by right and left-hand thread is fitted to indicate the central position of the bubble and from which its displacement can be easily read. Six rotatable scales give a direct reading in thousandths for the different throws.

As previously mentioned, one of the most important uses of this gauge is to ensure that wheels are coming from the quartering machines correct. At general repairs there is nearly always ovality, taper or angularity error, and it is good practice to quarter all pins in order to turn engines out with the pins as near correct as possible. Hence it is not politic to check all pins on arrival at the wheel shop. It is very desirable to know that when they come from the quartering machine the desired accuracy has been achieved. Therefore periodical checks on machined pins are made to ensure this.

A particular feature of value is that should the setting of pins be suspect on a locomotive in service, a fully accurate check can be made on all pins, whilst the wheels are under the engine. This enables the offending pair or pairs to be located with certainty and only these removed for rectification. It is my experience that when the phenomenon of slipping at high speed with steam off occurs the crank pins of at least one pair of wheels are out of angle. This gauge enables that pair or pairs to be identified with certainty.

In the quest for accuracy the wheels form a good starting point. They can contribute to improved results even though other factors do not initially keep pace, but, of course, until frames and horns and rods are brought up to the same standard the full benefits of closer tolerances cannot be obtained.

The setting of wheels at their theoretical axle centre in a quartering machine is not easy on account of their weight and varying journal diameters. An optical attachment has been developed so that this can be assured by direct sighting. Modern quartering machines support a pair of wheels from the journals and to set optically a hemispherical glass target is held truly coaxial with the axle centre by means of a spring-loaded magnetic carrier. The target graticule is a series of circles with 0·01in diametrical spacing and when these are centrally dispersed with the cross lines in the microscope the wheels are in the correct position in the machine.

It will be appreciated that the maintenance of the axle centres is vital in all these operations and a recessed centre to safeguard against damage to the edges is recommended.

Coupling Rods

The ideal method of finishing the bearing surface of coupling and connecting-rod bushes is for a final precision bore to be made after the bushes have been pressed into the rods. At the same time, in order to facilitate renewal at sheds when necessary, the final boring of the bushes must be central with the holes in the rod. Hence the holes in the rods must first of all be correct. The old method of trammelling must of necessity give place to positive measurement to ensure lengths being within the specified tolerances.

The coupling rod without its bushes is set on the rod bench, well supported in order to avoid any sagging, and self-centring gauging heads are placed in the rod bores and expanded by an internal sliding cone. These heads are provided with 3in diameter gauging plugs integral with the self-centring heads. The distance between the peripheries of the gauging plugs on any one rod is therefore equal to the centre distance of the rod bores, less 3in. Tubular length gauges are provided for checking rod length between centres, allowance being made for the 3in diameter gauging plugs.

For the convenience of applying limits, namely, plus or minus five-thousandths, the gauges are made 0·005in short. Therefore, if the gauge is admitted between the gauging points in conjunction with feeler gauges not exceeding 0·010in in thickness, the rod length is within specified limits.

The fit of bush in rod is becoming of greater importance with felt pad lubrication in order to effect an oil seal and, therefore, the ovality of bore is not allowed to exceed 0·010in. Should either the ovality or centre distance exceed the limits specified the rod is corrected by boring out either one, or both, of the bush holes, on a twin-spindle, vertical boring machine.

These methods may bring under review the practice sometimes encountered of making centres of trailing rods on narrow firebox engines long to drawing. This is very unmechanical and generally implies very slack fit of bush on crank-pin. Lengthy experience has shown that this is unnecessary if throughout accuracy is maintained and considerable advantages accrue from working strictly to standard.

It has taken a long time on steam engine practice to get away from the hand-scraped and bedded down bearing, but there is no doubt that the accurately machined finish is greatly superior and reduces initial wear. Such practice is essential in diesel engines and also applies to locomotive connecting-rods, both of the solid bush and split brass inside big end types.

These remarks have dealt with accuracy as applied to the fundamental mechanism of the steam locomotive. There are many other details upon which one could dilate, viz. firebox stays and taps, valve gear pins and bushes, but enough has been said. One detail on which initial clearance cannot be cut down to that utilised on other prime movers is the piston in cylinder and some advantage would accrue if it could, but apparently relative expansion is much more rapid.

At a period prior to World War II there was a considerable body of industrial opinion which regarded the railway workshops as a collection of primitive and antiquated machines and quite beyond the pale of making any contribution to wartime needs of production. Possibly this arose from the fact that, by statute, railway workshops have to stand aloof from the outside engineering industry, to deal with their own internal requirements only. The condition of their machine tools was probably well known amongst the machine tool makers who had derived considerable benefit during the slump years from the railways' practice of keeping equipment up to date, but industry in general and officialdom in particular had a complete misconception of the wide range of capacity necessary to provide for the mechanical and productive needs of a great railway.

During World War II the cloak was removed and the railway workshops became open doors to all who wanted help. But it took a little time to pierce the cloud. At the end of exploratory visits by the productive Ministries, the officials began to scratch their heads and exclaim: "We are on the wrong line—we have been looking to find out what you can produce—we should have been seeking what you cannot." Our own answer to Ministerial inquiries of "what can you do?" was very short and very sweet, viz. "Anything or anybody." One official of the Ministry of Aircraft Production exclaimed "You have the finest toolroom outside the aircraft industry." Later during the war he knew that there was hardly an aircraft factory which was not using ground thread taps produced in that toolroom. [The author then gave brief particulars of some outstanding jobs carried out in railway workshops during the war.]

These incidents have been quoted to indicate that British Railways' workshops are not behind in their quest for mechanical efficiency, and if the steam locomotive disappears, as well it may in a few years' time, the workshops are capable of dealing with any alternative mechanisms. If, for example, it is necessary to chase a tenth of a thou. round the plunger or bore of a diesel engine fuel pump or injector, that tenth can be found in a locomotive workshop on British Railways.

It is hoped that this address has vindicated its title. It was your president's thought to make the title "The British Locomotive: A Machine of Beauty and Precision." Until 1950 that would not have been inept, but with the advent of certain engines with a strong Continental or transatlantic appearance, it was thought that this would not now be suitable.

German Machine Tool Exhibition

No. II—(*Continued from page 445, September 23rd*)

AMONGST the machine tools exhibited at the recent Hanover exhibition was a particularly large jig boring machine with a vertical and a horizontal boring head. It was exhibited by Herman Kolb, G.m.b.H., Koln-Ehrenfeld. Direct reading optical setting equipment is fitted to each of the heads and the table of this machine, and with it the makers claim settings can be made to within 0·0001in. The table has a working surface 79in long by 47in wide and the vertical boring head has a transverse movement of 47in along the cross rail, whilst the horizontal head has a similar traverse on the column of the machine.

Each boring head is an independently driven unit with a boring capacity of up to 6in in steel. Two spindle speed ranges of 10 to 660 r.p.m. in twenty-four steps or 10 to 1000 r.p.m. in thirty-six steps are available, with eighteen feed rates from 0·002in to 0·095in per revolution. For milling purposes the table and the heads are arranged for a stepless range of feed speeds from 1in to 8in per minute.

The cross rail for the vertical boring head is guided on all sides of the ways on the right-hand column while on the left a special ledge provides an additional guide on the outside. A horizontal shaft with two worms drives the two traversing nuts simultaneously. The worm on the right column can be axially adjusted and to check the exact horizontal position, a spirit level is mounted on the cross rail. A motor, electrically interconnected with the vertical traverse drive, automatically locks and unlocks the cross rail.

For the table and boring head traverse drives d.c. motors are built in, to give infinitely variable speeds between 1in and 8in per minute. The rapid traverse speed is constant with 59in per minute and for the horizontal head it is 23in per minute. Table locking is effected by a push-button controlled motor, while boring head locking is effected hydraulically.

The optical setting equipments are so arranged on table and boring heads that the operator can observe the reading screens from one position. The screen for the table movement is fixed to the bed, while the other screens are attached to the boring heads themselves. The glass scales each have on their surfaces numbered hair lines which, by the optical system, are projected under suitable magnification to a focusing screen. By direct reading, using light gaps on the screens, head and table setting can be made to within 0·0001in.

Herman Kolb, G.m.b.H., is represented in this country by Stanley Howard, Ltd., 75/76, Exchange Buildings, Birmingham, 2.

The "Hyproma" production lathe (Fig. 5), built by Schulz and Braun, of Wiesbaden, has a bed consisting of two flame-hardened

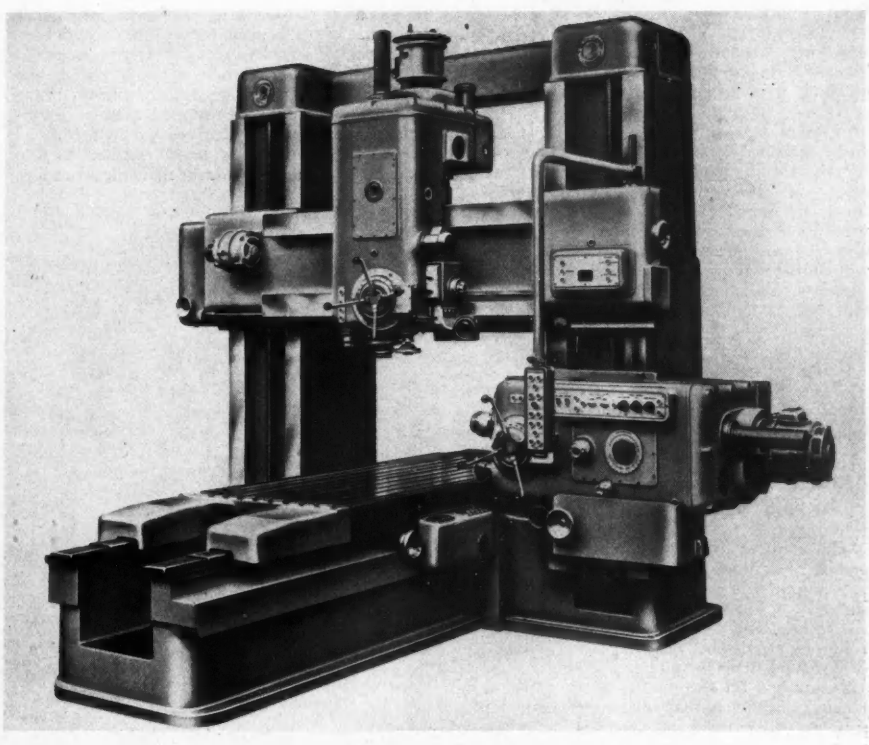


Fig 4—Large Kolb optical co-ordinate jig borer

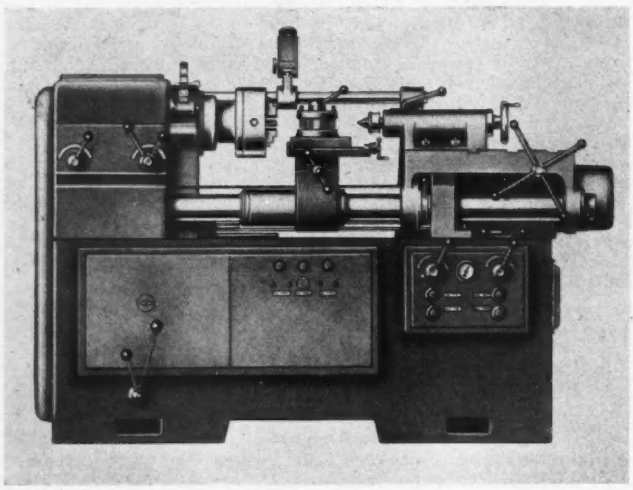


Fig. 5—" Hyproma " lathe with column bed-ways and hydraulically-operated saddles

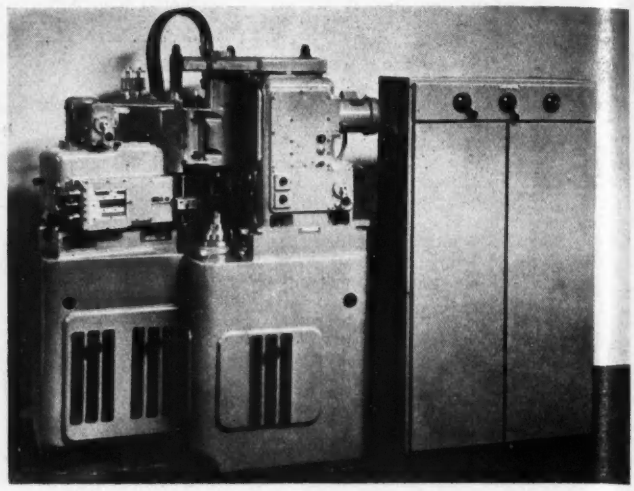


Fig. 6—Hessapp three-saddle vertical automatic lathe

columns of circular section, on which the saddle moves in adjustable bushings. It is stated that this design avoids one of the drawbacks of prismatic lathe beds, viz. the uneven wear which occurs on the guide surfaces. In general construction the lathe is very strongly built and capable of being used for rough turning as well as finish turning, while its accuracy makes it suitable for precision work. The guide columns are adjustable independently of head and tailstock, thereby increasing the accuracy. A hydraulic system serves to clamp the workpiece in the chuck and actuates the longitudinal feed, including a rapid traverse and a brake on the headstock spindle. The cross feed is normally by hand, but can also be supplied for hydraulic operation. The same holds for the tailstock spindle, which can also be hydraulic if required. Traverse of the tailstock bridge is obtained by means of capstan lever and rack and pinion, giving a long stroke. Easy replacement of the tailstock with a revolver head is possible and the latter can be hydraulically operated if required. Drive to the spindle is from the pole-changing motor over a three-step vee-belt drive and three-step gearbox, so that speeds from 95 to 1440 r.p.m. are available. The spindle itself runs in conical adjustable plain bearings, with ball thrust bearings to take axial loads. A thread-chaser can be supplied with the machine or it can be added subsequently.

A semi-automatic vertical lathe, illustrated in Fig. 6, was shown by Hessapp Hessische Apparatebau G.m.b.H. It is intended mainly for the simultaneous finish turning of workpieces with two or three different diameters, such as composite gear wheels or housings in which ball races are to be inserted. Depending upon the workpiece, the machine can be equipped with up to four vertical or horizontal tool supports, and can be used with or without a tailstock. Clamping is either hydraulic or by compressed air through the headstock spindle or by means of a special carrier and guide through the tailstock.

It is claimed for the vertical arrangement here adopted that it obviates the danger present in a horizontal lathe of swarf damaging the lathe bed, and that a greater variety of operations, such as surfacing, boring and taper turning can be carried out with one clamping of the workpiece. Each tool support is independently driven by a motor.

The main casting, which replaces the normal bed, has machined and ground surfaces on which are mounted the various supports. Inclined surfaces cast into the body allow a free flow of the chips. The spindle is driven at up to 3000 r.p.m. by a pole-changing 750/1400 r.p.m. motor of 2–5 h.p., through suitable vee-pulleys. These are mounted on the motor shaft by means of locking bushes so that changing them is very simple. All motors and switches are rated for up to 200 operations per hour. The headstock spindle is flanged according to DIN 55021 (size 4 or 5), hardened and ground, and runs in precision ball bearings with a guaranteed accuracy of 0·002mm.

At each support the drive is from the motor through gears and magnetic clutches. For the rapid traverse a safety multi-disc clutch is provided and for the feed there is a safety clutch which also limits the torque transmitted, so that the supports can be run against rigid stops, thus terminating the cut at a constant point every time. The supports are completely self-contained and each is adjustably mounted on its base by four bolts. Normally, standard universal tool-holders are fitted which allow the tool to be set by means of special hydraulic arrangements. After inserting the workpiece and operating the clamping push button, the operator starts the machining cycle, which proceeds completely automatically to the end, when the spindle stops, the clamping is released and the machine returns to its original position.

Our illustration, Fig. 7, shows a turret lathe made by Vulkanhammer-Maschinenfabrik, Berlin-Neukölln, which can be supplied with eighty-eight spindle speeds from 7 to 1400 r.p.m. (step ratio 1·06) or, alternatively, with twelve spindle speeds from 22·5 to 1090 r.p.m. (step ratio 1·41), both series of speeds being for either sense of rotation. Speed control is electro-mechanical and can be actuated either from the headstock or saddle, while the machine is actually in operation. A heavy brake allows the lathe to be stopped almost instantaneously. The back gear is situated below the headstock spindle and can be operated by the cranked lever shown, while the machine is running down. The headstock spindle is provided with a large central bore, and runs in adjustable cylindrical bearings which are pressure lubricated. For cutting steep threads, feeds and leads can be increased tenfold, and no 127-tooth change wheels are required. The feed gearbox for cylindrical turning and surfacing is equipped with an overload-release disc coupling, so that turning can be carried out against solid stops. The interlocked controls for start, stopping and right-hand or left-hand cutting speeds and feeds are all assembled on the apron. The machine can be operated fully automatically, including indexing of the turret. For surfacing, the centralising pin used when boring is automatically retracted. All controls are such that surfacing and cylindrical turning operations can succeed one another in any order. The London agent for this firm is Soag Machine Tools, Ltd., S.E.11.

A small copying shaper was shown by Walter Bartsch, Berlin, N.20. It is hydraulically-operated, with the advantage that damage to workpiece or machine due to faulty handling is obviated. The template is to the same scale as the finished workpiece and is fixed to an arm of the table, which moves in 45 deg. steps, so that shaping of slopes of up to 80 deg. is possible. Without stopping the machine, the cutting speed can be steplessly adjusted, and so can the cutting stroke and the table feed. Immediate stopping in any position is possible, and the cutting tool can be changed quickly by removing the tool-holder flap and replacing with another in which a new tool has been mounted.

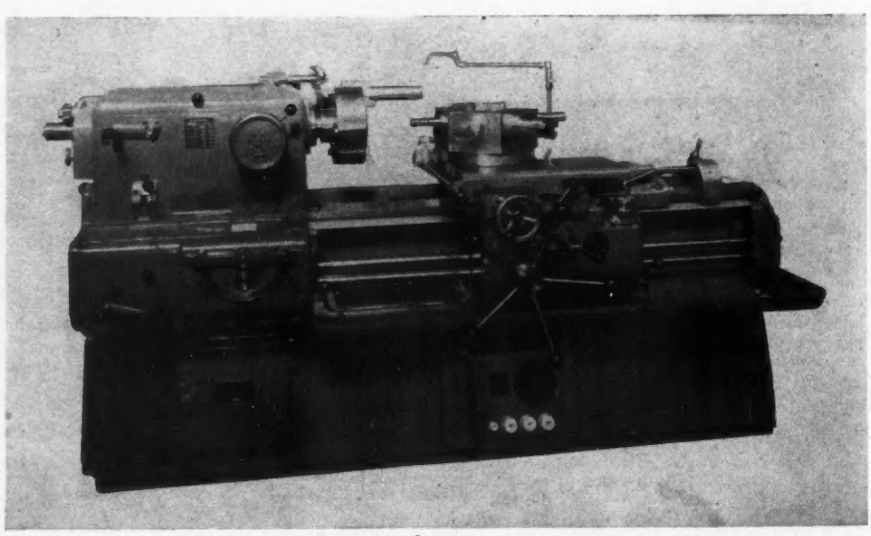


Fig. 7—Turret lathe with spindle speed adjustable in small stages while running

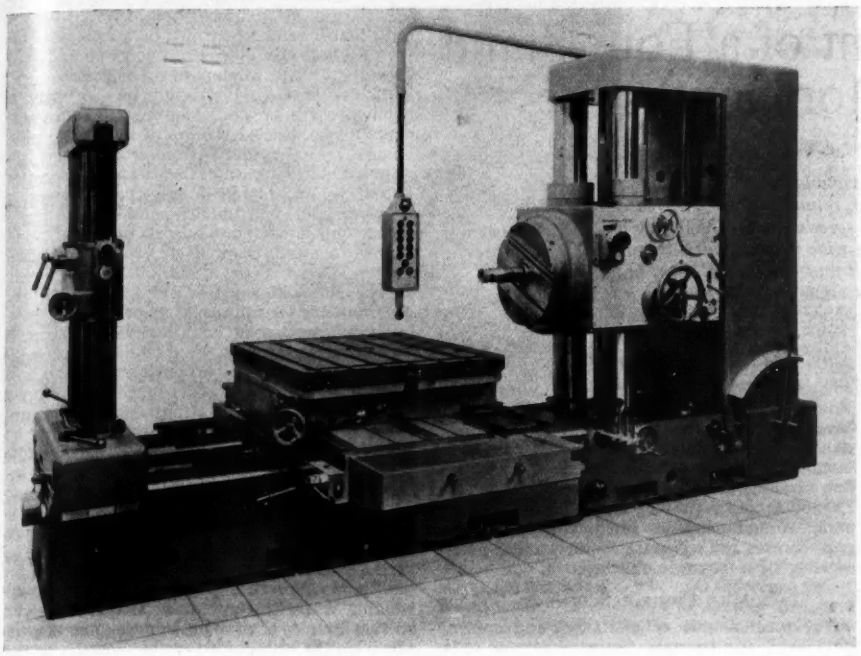


Fig. 15—Horizontal boring mill with column guides for workhead and boring bar support. It is fitted with optical positioning and programming systems

Greatly increased stiffness and freedom from vibration are the chief characteristics of the boring mill illustrated in Fig. 15, which is made by Scharmann and Co. G.m.b.H., of Rheydt (Rhineland). These are achieved by the use of column guides which carry a large proportion of the weight of the workhead, while the main casting takes any end thrust. These columns are flame-hardened and finish-ground. Between them is situated the boring spindle which is driven by a pole-changing motor over a "P.I.V." infinitely variable gear, at speeds ranging from 8 to 1125 r.p.m. A tool ejector mechanism has been fitted to the spindle. The face plate runs on adjustable pre-loaded precision ball bearings and has a diameter of 560mm. Quill feeds of 0·4mm to 625mm per minute and longitudinal table feed motion are provided by a single motor, while a second motor provides infinitely variable speeds of 10mm to 625mm per minute for the vertical movement of the headstock and the transverse and rotary movement of the table, which is clamped or freed by turning a handwheel and can be indexed through 90 deg. by the use of a built-in indexing device. A rapid traverse motion of 2000mm per minute has been provided for the quill and table. Characteristic for this machine is the "Micromess" optical scale and setting system which has been developed to allow programme control and fully automatic positioning. A glass scale illuminated over its whole length is freely supported in a housing provided with rubber flaps to exclude dust and prevent glare. The scale is read by means of a microscope which can be traversed by turning a screw, the translation being shown on a dial indicator graduated to 0·0005in. With programme control the settings are transferred to a second interchangeable glass scale which thus contains a record of the programme to be carried out. In automatic operation stops are set near the working positions which cause the machine to change over from the rapid traverse to an inching movement of 2·73mm per minute. When the exact position is reached the inching movement is also stopped and the machine locked. Experiments are stated to have shown that the accuracy of this method is approximately 0·005mm. The bed of this machine has three support surfaces, of which the central one acts as a guide, preventing lateral displacement. Charles Churchill, Ltd., Birmingham, is the agent for this machine in the United Kingdom.

(To be continued)

Resignalling of Camden Town Junction

THE resignalling of the Camden Town Junction on the Northern Line, just completed by London Transport, has involved the replacement of the previous manual signal cabin by interlocking machines which are remotely controlled through the train description apparatus. Camden Town is the most important junction on the London Transport tube lines, and over 1200 trains pass through it daily. Hitherto it has been controlled by a manual signal cabin fitted with forty-six levers, and the new installation, which allows completely automatic signalling and automatic routing of trains passing through it to all destinations, is the first of its kind.

Trains pass through the junction to and from two branches to the north—Edgware and Barnet—and two branches to the south—the Charing Cross and City sides of the Northern Line. The signals worked from the station are located at Camden Town itself and at Belsize Park, Chalk Farm, Kentish Town, Mornington Crescent and Euston. All routeings which have hitherto been signalled from the Camden Town cabin will now be signalled automatically, together with the appropriate point movements, by means of train descriptions set by the signalmen at Edgware, East Finchley and Kennington cabins.

The new apparatus for the operation of the signalling consists of three interlocking machines in separate relay rooms ; two at Camden Town for signalling the northbound and the southbound trains respectively, and the third at Mornington Crescent station for the signalling in the Mornington Crescent area. Three separate interlocking machines have been introduced to simplify installation and to make maintenance easier. This installation also gives increased reliability as in the event of any defect at one of the three relay rooms only a portion of the equipment would be affected.

The interlocking machines are similar to the first machine of the type installed in 1954 at Aldersgate on the Circle Line, and described in our issue of June 10, 1955. Each machine comprises twelve shafts, allowing some spare shafts, and the three machines together control a total of fifteen signals and seven pairs of points. To work with the interlocking machines, the existing train description apparatus has been suitably modified and added to by relays and circuits installed in a special relay room at Camden Town station. The required route for each train is stored by the train description apparatus at Camden Town and in due course relays cause the new interlocking machines to set up and signal the route through Camden Town. Trains in the converging junctions are signalled automatically on the principle of giving priority in order of arrival. Northbound trains, whether coming from City or Charing Cross, are automatically passed through the junction and routed to Edgware or Barnet in accordance with train description set by the Kennington signalmen. Southbound trains, whether coming from Edgware or Barnet, are routed through Camden Town to the City or Charing Cross in accordance with the description set by the signalman at Edgware or East Finchley.

Complete interlocking ensures that no unsafe or conflicting movements can be signalled, and the installation is the first in which signalling at a major junction has been controlled remotely through the train description apparatus. While the entire installation will operate automatically in the normal way, provision has also been made for push-button remote control operation of the interlocking machines from Camden Town when this may be necessary.

From a control room on the site of the former signal cabin at Camden Town, which can be seen in the photograph we reproduce, the interlocking machines can be operated when required through a panel of eighteen three-positioned push-buttons. A set of nine switches are provided to make the changeover from automatic to push-button control, so that only the group of push-buttons required to be used need to be switched in, and an illuminated track diagram and train description diagrams are installed.

The new installation has been carried out by Mr. Robert Dell, signal engineer, under the direction of Mr. C. E. Dunton, the chief civil engineer of London Transport, and the work has been carried out by the signals staff over a period of nine months without interruption to traffic. The interlocking machines themselves were in actual operation for some time before the completion of the work and were operated manually by a temporary lever frame at Camden Town.

Control room at Camden Town station with push-button control panel for operating interlocking machines when necessary

Electrical Equipment of a Four-Stand Strip Mill in Monmouthshire

By P. C. DANNATT, B.A.

A four-stand tandem cold strip mill was commissioned in February, 1954, at the Newport (Monmouthshire) Works of the Whitehead Iron and Steel Company, Ltd. It is designed to operate at final strip speeds of up to 2000ft per minute ; strip of low to medium carbon steel up to 14in wide and ½in thick is rolled down to a minimum of 0·03in. The work rolls of all four stands are 10½in in diameter and are direct driven through pinion stands. Coiling is under tension, a belt wrapper being used to start the coils. The mechanical portion of the mills was manufactured by Davy and United Engineering Company, Ltd. The electrical equipment supplied by Metropolitan-Vickers Electrical Company, Ltd., represents the company's latest practice in this kind of drive and is described in this article.

THE work rolls of the new four-stand tandem cold strip mill (Fig. 1) at the Newport works of the Whitehead Iron and Steel Company, Ltd., are electrically driven through pinion stands. Coiling of the strip is effected under tension, a belt wrapper being used to start the coils.

The leading particulars of the main driving motors are given in Table I. The stand and reel

TABLE I—*Main Driving Motors*

Drive	Power, h.p.	Speed, r.p.m.	Voltage
Stand 1...	1000	0/168/436	0/500/500
Stand 2...	1000	0/226/580	
Stand 3...	1000	0/300/780	
Stand 4...	1000	0/300/780	
Reel	300	0/180/450	

motors are all built in accordance with BS169 for a maximum temperature rise of 50 deg. Cent. and overload capacities of 100 per cent momentarily and 25 per cent for two hours. They are shunt-wound separately excited series-stability-compensated machines with auxiliary windings on the interpoles. Each stand is direct driven by a 1000 h.p. motor, as shown in Fig. 2.

The motors are open protected machines with two pedestal oil ring lubricated bearings, the driving end bearings being fitted with thrust collars. Mechanical overspeed trip devices are fitted and chain-driven tacho-generators on the stand motors. The reel motor has a 30in brake at the non-driving end.

Power for the mill is supplied from a seven-machine Ward-Leonard m.g. set consisting of a 5000 h.p., 1000 r.p.m., 6000V, synchronous motor driving four identical 800kW and one 250kW shunt-wound, separately excited, series-stability-compensated generators supplying the stand and reel motors, the set being completed by an exciter for the synchronous motor. Protected type Class B machines are used throughout and are fitted with ring-lubricated journal bearings complete with thermostats. The synchronous motor is designed to run at 0·8 power factor leading on full load ; it is reactor-started. The m.g. set reactor, field cubicle, mill d.c. control gear, and exciters are placed together in a motor room adjacent to the mill.

The excitation and control machines (Table II)

TABLE II—*Exciter Sets*

Macnine duty	Power, kW	Voltage	Type
Main set :			
Constant potential	30	250V d.c.	Self-excited, level-compounded
Generator exciter	12·5	250V d.c.	Shunt wound, separately excited
Master pilot... ...	10	500V d.c.	Shunt wound, separately excited
Driving motor ...	75 h.p.	500V a.c. 3-phase	980 r.p.m. squirrel cage
Stand sets, Nos. 1, 2, 3 and 4 :			
Motor exciter ...	6	250V	Shunt wound, separately excited
Generator field regulator	3·6	—	Metadyne
Ohmic drop compensation	1·2	—	Metadyne
Driving motor ...	15 h.p.	500V a.c. 3-phase	1460 r.p.m. squirrel cage
Reel set :			
Generator exciter...	3·6	—	Metadyne
Motor exciter ...	1·2	—	Metadyne
Mill current limit...	3·6	—	Metadyne
Driving motor ...	15 h.p.	500V a.c. 3-phase	1460 r.p.m. squirrel cage

have been divided into a main exciter set, four stand exciter sets, and a reel exciter set. Other small electrical machines include two screw-down motors on each stand ; they are 7·5 h.p., 750/150 r.p.m., 500V d.c., totally enclosed, compound-wound machines fitted with 8in "Perigrip" brakes and selsyn transmitters and coupled together by a magnetic clutch.

Mill Control Scheme

The main source of excitation and control supplies is the constant potential exciter (*CP*, Fig. 3). The exciter is level compounded, and a carbon pile "VP" voltage regulator is also provided. Changeover to the 250V shop supply is also possible in an emergency.

The overall mill speed is determined by the voltage obtained from a motor-operated rheostat

Fig. 1—The four-stand cold strip mill at the Newport works of the Whitehead Iron and Steel Company Ltd. The stand control cabinets can be seen, No. 4 stand delivery cabinet being on the right

potentiometer connected across the master pilot exciter *MP*. The master pilot exciter output only provides a control signal to the generator field regulating metadynes : these act as positive-negative boosters in series with the generator fields, which are all supplied from a generator exciter *GE*. This machine has its field in circuit with a winding on the master rheostat. It will be seen, therefore, that the steady-state generator-exciter voltage will keep approximately in step with the master pilot output voltage.

As the speed of a stand motor for a given field setting is proportional to its generator voltage (neglecting for the moment the slightly drooping speed-load characteristic of the motor) it is necessary to regulate the generator voltage to the same value as the master pilot voltage, or a selected portion of it. The method is indicated in Fig. 3, which shows the control for one stand.

The master pilot output feeds four potentiometers, one for each stand. Part of the potentiometer is wound on the first half of travel of one ring of the coarse speed rheostat. The position of this rheostat determines the proportion of the master pilot *MP* voltage (minimum of 75 per cent) that is balanced against the main generator voltage, and the difference signal so obtained feeds the control winding of the generator regulating exciter, *GR*. It will thus be seen that the regulating exciter holds the generator voltage equal to the selected portion of the master pilot voltage. The regulating exciter being a high-response machine ensures that the main generator output voltage rapidly follows any changes in either overall mill speed or individual stand speed settings on the master rheostat and stand coarse rheostats respectively. The regulating exciter is only a small machine, as it merely supplies the difference in voltage between the generator exciter and master pilot output.

The scheme as so far described takes no account of the decrease in stand speed that will occur with increase of load on the particular stand. This is of some importance, especially when setting up a new rolling schedule, as the stand motors are identical machines, but the loading may be different on different stands. The signal on the regulating exciter (metadyne) is therefore increased by the output voltage of the "ohmic drop" metadyne, *OD*, whose control winding is fed with a signal proportional to main armature current. The strength of this signal can be varied to adjust the amount of speed regulation or ohmic drop compensation. A speed-up winding is also incorporated on this metadyne so that by means of a push button the control signal on the ohmic drop exciters and hence the generator regulator may be temporarily increased, so speeding up that stand to adjust the amount of strip between adjacent stands.

It has been shown how the coarse rheostat on each stand determines the stand voltage as a proportion of the master pilot voltage. The second track on this rheostat operates over the second half of travel to weaken the motor field over a range of approximately 2·5 : 1. The rheostat is in the motor exciter field circuit. A third track is used for the auxiliary interpole circuit over the field weakening range, while a fourth track (not shown in Fig. 4) is connected to a suitably calibrated voltmeter to show the rheostat position at the mill cabinet. A further vernier rheostat, also in the motor exciter field circuit, provides fine adjustment of motor speed.

Another important part of the mill scheme is the current limit control necessary under emergency stop conditions. When an emergency stop button is pressed the effect is to open and discharge the master pilot exciter field. As a consequence the master pilot output immediately collapses. The generator field regulating metadynes therefore immediately buck down the generator fields, and this effect is increased by the collapse of the generator exciter output, which is also initiated by the emergency stop

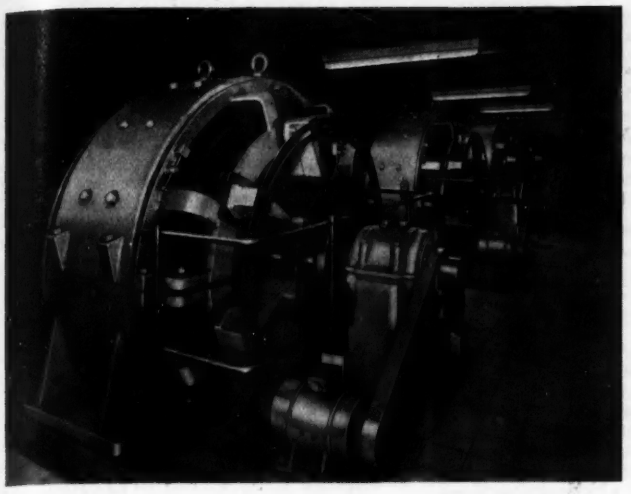


Fig. 2—The 1000 h.p. stand driving motors (No. 4 motor in the foreground) showing the chain-driven tacho-generators

button. The result is a very rapid collapse of the generator fields, and the consequently high regenerative current in the armature circuits brings the mill rapidly to rest. If the mill is running fast, however, when the stop is initiated, the regenerative currents could exceed the overload capacity of the machines. This is prevented by injecting a voltage into the master pilot circuit by means of the current limit metadyne, *CL*. This machine has a bias winding, which would give it an output in opposition to the master pilot voltage, but owing to the metadyne being short circuited by a rectifier no signal is possible from the metadyne under this condition. The control winding on the metadyne is however, connected across a shunt and transformer in the armature circuit of stand 4. (This stand is chosen as, being the fastest, its regenerative current will be greatest.) Thus, when the current reaches a sufficiently high value for the control signal on the metadyne to exceed the bias signal a voltage is produced by the metadyne, and this tends to replace the master pilot voltage, so slowing down the decay of voltage in this circuit. The collapse of the generator fields must follow this voltage, and therefore the regenerative current is held within the permissible limit set on the current limit bias winding.

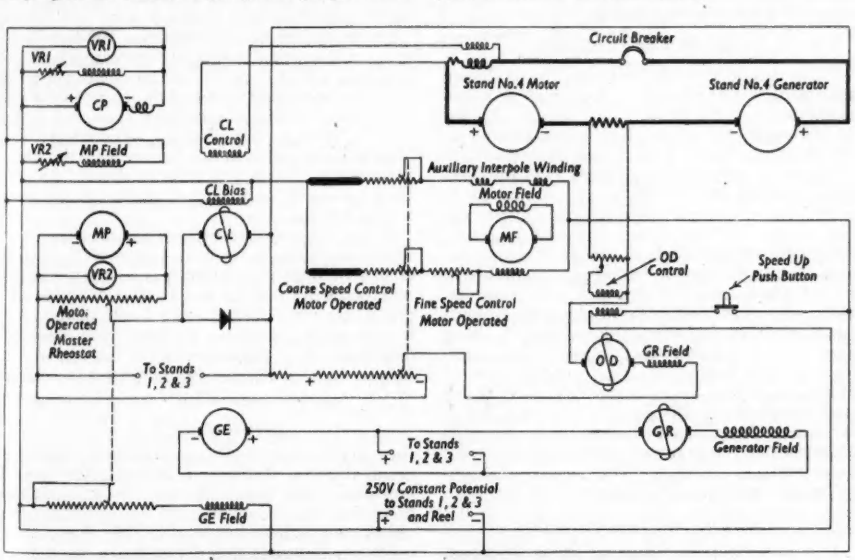
Reel Control Scheme

The reel control is of the usual Metropolitan-Vickers design, constant tension being obtained by keeping the reel motor input power proportional to the strip speed. The strip speed signal is obtained from the tacho-generator on stand 4 and feeds the reference field on the reel motor field metadyne. The metadyne feed - back winding is connected across the reel motor armature. Reel motor, weak and full field limits are provided by a magnetic amplifier fed from shunts on the field and feeding a limit winding on the metadyne circuit. Current control is effected by an ampere-turn balance on the reel generator field metadyne between an adjustable tension reference signal and a current feedback (incorporating a rate of change signal) from the armature circuit.

The voltage or speed limit circuit usually comes into action when the end of the strip leaves the last stand. A voltage difference signal between the stand 4 tacho-generator and reel generator voltages excites the limit amplifier when its value exceeds about 10V. The same amplifier is used for inertia compensation, of which only one step is provided as the build-up range is only 2 : 1. The amplifier feeds a limit winding on the generator metadyne.

Control Equipment and Operation

The mill is operated from an entry and exit cabinet provided on each stand, as shown in Fig. 1. The master controls are mounted on the exit cabinet of stand 4. The contactor control equipment is mounted on two 55ft open type boards placed back-to-back in the motor room. One board comprises motor, generator and instrument sections for each stand and the reel, and master pilot, generator exciter and relay panel sections. The other board comprises the starters for the exciter sets, four screwdown and a constant potential excitation sections, an oil pressure and bearing thermostat relay and indication panel, and incoming a.c. and d.c. supply panels. The two boards are placed 14ft apart with a 2ft wide centre framework, on which are mounted the motor-operated rheostats controlling stand and mill speeds, resistance banks, transformers and magnetic amplifiers. The panels are thus left free of these heavy and bulky items, and the rack permits access from both sides.



CP—Constant potential exciter.
MP—Master pilot exciter.
CL—Current limit metadyne.
MF—Motor field exciter.
GE—Generator exciter.
GR—Generator regulating exciter (metadyne).
OD—Ohmic drop metadyne.
VR—Carbon pile voltage regulator.

Fig. 3—Simplified schematic diagram for No. 4 stand control. A similar scheme is used for the control of the other three stands

Of the eight cabinets, mounted on the mill stands, from which the mill is controlled, the fronts of the four delivery cabinets can be seen and the backs of the entry cabinets also are visible in Fig. 1. The entry cabinets and delivery cabinets for stands 1, 2 and 3 provide for setting up and threading, after which the mill is controlled by one man from stand 4 delivery cabinet, which also contains the reel controls.

The entry cabinets are provided with an inch selector and control switches, making it possible to inch the respective stand individually or in combination with the preceding stands. On these cabinets are also mounted preset button, an emergency stop button, stand extractor fan buttons and lighting switch, and a number of indication lights.

The delivery cabinets are more comprehensive as can be seen in Fig. 1. The same inching facilities are provided as on the entry stands, and interlocking is provided so that once inching of a stand has been selected at one point it can under no circumstances be inched from any other point. In addition to inching controls the delivery cabinets also carry the screwdown controls and indicators, comprising a screw selector for " left-both-right," a two-speed " up-stop-down " controller, and two counter type indicators. The controllers for the coarse speed control rheostats and the vernier speed control motor-field rheostats are also mounted on these cabinets, together with the speed-up, emergency stop and reset buttons. Instruments on each cabinet show the stand strip speed (in feet per minute) and current and the coarse and vernier rheostat position.

The delivery cabinet for stand 4 includes the overall mill and reel controls and is therefore the largest of all. The reel controls comprise a selector for " free inch," " off " and " tension "; under the last condition the reel runs in unison with the mill (or under voltage limit in the absence of strip). A separate inch controller, " forward-off-reverse," is provided for free inching the reel. There is also a button for casting off tension from the mill. The actual value of tension is set by means of the handwheel (on the right of the off-gauge indicator, Fig. 1) which turns a rheostat in the reel generator metadyne reference circuit.

To run the mill the inch selector on stand 4 delivery cabinet is turned to the " run " position, which is an extra position on this selector switch. The reel selector will normally be put on the " tension " position. The master controller for the mill, the centre controller in the top row (Fig. 1), is provided with off, thread, hold and fast positions. Putting the master controller at " thread " will run the mill up to a preset slow speed. Turning it to " fast " will run the master rheostat and hence the mill to the Ward-Leonard speed set on the preset speed handwheel on the left-hand side of the cabinet. (The actual speed of each stand will, of course, depend on the positions of the coarse and fine rheostats as already mentioned.) An extra voltmeter on this cabinet shows the stand 4 voltage. Finally, by turning the master controller to " hold," acceleration or deceleration of the mill may be halted at any point.

The actual rate of acceleration of the mill is fixed by the speed of the master rheostat, which is not under the control of the mill operator. Similarly, the degree of ohmic drop compensation is determined by the speed of the master rheostat, but its value may be varied within certain limits by means of four individual rheostats behind the control board.

Besides the instruments on mill cabinets, instrument panels are provided on the control board for the mill, each stand and the reel. The mill instruments include the master pilot output, generator exciter, and current limit metadyne voltmeters, and the stand and reel instrument panels include main ammeter and voltmeter, generator and motor field ammeters, and a full set of metadyne instruments. A fault selector switch is also mounted on these panels and enables rapid checking of the safety circuit in the event of the safety relay failing to close.

Lightweight Metal Fixing Systems.—A code of design practice and manual for lightweight metal fixing systems for building linings and ceilings has been published by the Metal Fixing Association, 32, Queen Anne Street, London, W.1.

Metallurgical Topics

Structural Changes During Creep

LOW-ALLOY steels, stressed in the region of the creep limit as determined by short-time creep tests, are sometimes found to fail on more prolonged loading at the same temperature with very little deformation, and often with an intercrystalline fracture. Such intercrystalline fractures have occurred after relatively short service in screwed bolts and other components of high-pressure steam installations. This has led to greater attention being given to long-time tests. The relative behaviour of normalised, and of normalised and tempered, low-alloy steels containing molybdenum in short- and long-time creep tests at 550 deg. to 650 deg. Cent. was recently studied by J. Glen[1] who found that at any given temperature the elongation at fracture in stress-rupture tests first decreased with increasing time to fracture and then increased with still longer times. As the temperature of testing was reduced, a longer time was required to reach the minimum elongation, and the minimum elongation decreased with decreasing temperature. It was found that at high stresses and/or temperature the normalised and tempered material was inferior to the normalised, but the steel, normalised

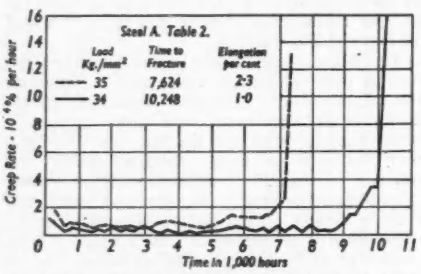


Fig. 1—Creep rate at 500 deg. Cent. of 0·04 per cent carbon, low nickel-chromium-molybdenum steel, air cooled from 930 deg. Cent. and tempered at 570 deg. Cent.

and tempered at 650 deg. Cent. and above, tended to be better the lower the temperature and/or the smaller the stress applied.

A study of the behaviour, comparable in some respects, of a nickel-chromium-molybdenum steel was the subject of a recent paper entitled "Changes in Structure of Chromium-Nickel-Molybdenum Steels on Prolonged Heating Under Load at 500 deg. Cent.," by F. Wever, A. Krisch and H. J. Wiester.[2] They state that the steel containing carbon 0·1, silicon 0·3, manganese 0·4, chromium 0·7, molybdenum 0·8, and nickel 1·5 per cent, which had given premature failures with intercrystalline fractures and little deformation when used as screwed bolts, had proved to be satisfactory in its use in turbine rotors and blades, in which the stressing is always lower and more uniform than in screwed bolts, especially at the root of the threads where the highest stresses occur. They found that the cause of the grain-boundary damage which was developed as a result of the prolonged loading at 500 deg. Cent. and which was accompanied by a lowering of impact value, was not satisfactorily explained by metallographic observations, and they therefore extended their long-time tests by isolating and analysing the carbides present, to ascertain what changes occurred in the carbide phase during the prolonged heating. The experiments were carried out on the low-carbon nickel-chromium-molybdenum steel known to be susceptible to intercrystalline failure on prolonged loading; and as the steel approved for heat-resisting screws nearly always contains higher carbon, the influence of increased carbon content was studied; so also was the influence of hardening and temperering and of isothermal transformations.

Creep and Stress-Rupture Tests

Measurements were made in tests of up to about 10,000 hours duration (in one case 16,000 hours) of the creep and fracture properties at 500 deg. Cent. of five heat-resisting nickel-chromium-molybdenum steels of composition shown in Table I in different conditions of heat-treatment (air- or oil-hardened with tempering at 570 deg.

TABLE I—*Chemical Composition, per cent*

Steel	Carbon	Chromium	Molybdenum	Nickel
A	0·04	0·48	0·72	1·42
B	0·14	0·77	0·94	1·60
C	0·16	0·93	0·75	1·46
D	0·24	0·90	0·74	1·47
E	0·30	0·89	0·75	1·48

Cent. isothermally transformed at 350 deg. and at 450 deg. Cent., and oil- or water-quenched with tempering at 620 deg. to 660 deg. Cent.).

The behaviour of the steel was found to depend on the tempering temperature and its effect on the carbide phase rather than on the influence of the transformation products of the $\gamma \rightarrow \alpha$ transformation. All steels which were tempered at 570 deg. Cent. or transformed at 350 deg. or 450 deg. Cent. showed a higher short-time (D.V.M.) creep limit and a higher 1000 hour rupture strength, but in all cases gave intergranular fractures with little deformation. On the other hand, by tempering at 620 deg. to 660 deg. Cent. (according to the carbon content of the steel) a lower D.V.M. creep limit and a lower 1000 hour rupture strength were obtained, but the specimens broke with good elongation and reduction of area. The figures in Table II afford typical examples of this behaviour.

detached from the surface of the steel and remained embedded in the surface replica so that observations of their form and size were possible. The tests were made mainly on the steel in the air-hardened condition with the lower tempering temperature, and in the oil-hardened condition with both lower and higher tempering tempera-

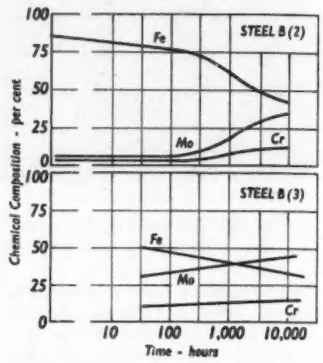


Fig. 2—Change in composition of carbides in 0·14 per cent carbon, low nickel-chromium-molybdenum steel, oil hardened and tempered at (*a*) 570 deg. Cent. and (*b*) 640 deg. Cent., during creep tests at 500 deg. Cent.

TABLE II—*Results of Long-Time Creep Tests at 500 deg. Cent.*

Steel	Heat-treatment, deg. Cent.	D.V.M. creep strength, kg/mm²	Load, kg/mm²	Duration of experiment, hours	Elongation at fracture, per cent
A (1)	930 deg./air, 3 hours 570 deg./air	37	35	7624	2·3
(2)	930 deg./salt, 450 deg. 2 hours	38	34	10248	1·0
(3)	930 deg./water, 2 hours 660 deg.	28	30	221	7·9
B (1)	930 deg./air, 3 hours 570 deg./furnace	50	40	9677	0·6
			35	6228	0·5
(2)	930 deg./oil, 3 hours 570 deg./furnace	>40	40	2738	1·4
(3)	930 deg./oil, 3 hours 640 deg./furnace	~22	20	16082	2·2*
C (1)	930 deg./air, 3 hours 570 deg./air	53	50	2389	1·5
(2)	930 deg./salt, 450 deg. 2 hours	51	38	5940	1·0
(3)	930 deg./oil, 2 hours 620 deg.	29	30	5222	10·9
D (1)	930 deg./air, 3 hours 570 deg./air	55	50	3828	0·8
(2)	930 deg./salt, 450 deg. 2 hours	48	50	2520	0·6
(3)	930 deg./oil, 2 hours 630 deg.	24	25	11403	13·5
E (1)	930 deg./air, 3 hours 570 deg./air	52	50	1244	0·9
(2)	930 deg./salt, 450 deg. 2 hours	52	50	3167	0·9
(3)	930 deg./oil, 2 hours 630 deg.	24	24	7920	16·1

* Unbroken.

NOTE: Conditions for the D.V.M. test are maximum creep rate per hour, 1×10^{-6}; maximum creep, 0·2 per cent in 45 hours.

In the paper the results are also set out in diagrams of the type shown in Fig. 1.

Isolation of Carbides

On isolating the carbides it was found that in specimens not tempered, or tempered at a low temperature, precipitation of finely divided Mo_2C began to set in during the heating at 500 deg. Cent. and became evident after more than 500 hours. It may be assumed that this precipitation, or the condition giving rise to it, is the cause of the relatively high creep resistance; but, on account of the high resistance of the grains, flow begins to take place in the grain boundaries and eventually results in tearing them apart. In specimens tempered at a higher temperature, most of the precipitation would already have taken place in the tempering treatment, giving particles of larger size. By this, and by the resulting impoverishment of the ground mass in molybdenum, the lower creep resistance of the steel tempered at 620 deg. to 660 deg. Cent. is explained. The grains themselves are more readily deformed and the relative stress on the grain boundaries is lowered. The change in composition of the carbide is illustrated in Fig. 2.

Electron Microscope Study

In continuation of the work already described, a study of the structural changes in long-time creep tests at 500 deg. Cent. shown by steel B of Table I was made by means of the electron microscope by F. Wever and Angelica Schrader.[3] By a special etching technique, carbides were

tures. In the air- or oil-hardened steel, the very fine precipitate of MO_2C first formed had hardly increased in size after 9677 hours at 500 deg. Cent. In the oil-hardened steel with high tempering temperature, a MO_2C precipitate of relatively large particle size already appeared on tempering at 640 deg. Cent., and the precipitation increased as the time of heating was prolonged. There were also large carbide grains in the former austenite grain boundaries. These grains were already present after tempering and did not change in the prolonged heating.

These observations support the idea that the distinct difference between the steel tempered at low or high temperatures is to be traced to differences in the form and amount of the Mo_2C precipitate; but further work would be required to determine the extent to which the observed differences in arrangement of the carbide in the former austenite grain boundaries are related to the behaviour on fracture.

Effect of Nickel

In the discussion of these papers, E. Houdremont drew a distinction between the grain-boundary brittleness shown by the nickel-chromium-molybdenum steel in these experiments and temper-brittleness. He referred to the fact that the addition of nickel to a chromium-molybdenum steel was sometimes held to have a deleterious effect. In his opinion, nickel produced a general improvement and gave a steel of very high D.V.M. creep strength at 500 deg. Cent. if treated with this object. It had no specially

damaging influence, since, at a lower creep strength (i.e. when originally brought into a somewhat better state of equilibrium by the use of a higher tempering temperature), this steel behaved no worse in fracture tests than other steels of similar D.V.M. creep strength. The nickel-chromium-molybdenum steel in these experiments had been tested under very high stresses up to 50kg per square millimetre (31·75 tons per square inch). If the stresses used had been as low as those generally applied to chromium-molybdenum-vanadium steels, for example, it seems very probable that no embrittlement would have taken place in suitably treated nickel-chromium molybdenum steel.

REFERENCES

[1] *Journal of the Iron and Steel Institute*, April, 1955, page 320.
[2] *Archiv für das Eisenhüttenwesen*, August, 1955, page 463.
[3] *ibid*, page 475.

Hair-Line Cracks

IN spite of co-operative researches like those of the Alloy Steels Research Committee and the individual work of many investigators, there are still differences of opinion about the cause of the formation of hair-line cracks. These differences are briefly summarised, and an attempt is made to resolve them, in a paper by A. W. Dana, Jr., F. J. Shortsleeve and A. R. Troiano, on the "Relation of Flake Formation in Steel to Hydrogen, Microstructure and Stress."*

Of the many theories advanced, only two were considered by these authors as plausible explanations of the mechanics of the formation of hair-line cracks or flakes as they are generally called in America :

(1) The hydrogen pressure theory, which states that the immediate cause of flaking is the pressure exerted by entrapped hydrogen gas that collects in small internal cavities or voids during cooling. When the temperature of the steel is low enough to preclude extensive plastic flow, the cavity pressure causes local brittle fracture (flakes).

(2) The micro-segregation and transformation stress theory, according to which flaking results from stresses arising from the volume changes accompanying the formation of martensite and/or low-temperature bainite after a large portion of the section has transformed at elevated temperatures.

Supporters of the hydrogen theory agree that stresses from other causes may be additive to the stresses produced by hydrogen, and may in some cases provide the increment in stress necessary to produce flakes. They maintain, however, that no stress except that produced by hydrogen pressure is sufficient in itself to produce flakes. On the other hand, the transformation stress theory does not rule out the embrittling effect of hydrogen, but states that flaking does not occur in the absence of transformation stresses. The industrial success of precautionary treatment against the formation of hair-line cracks does not help to discriminate between the two theories, since a successful treatment will, at the same time, complete the transformation of austenite before the steel is cooled to room temperature, and reduce the hydrogen content to a value below which flaking does not occur.

EXPERIMENTAL PROGRAMME

The investigation undertaken was designed to assess the relative importance of the effects of transformation stresses and hydrogen by separating the two variables. Six steels were used of the following percentage composition :—

S.A.E.	C	Mn	Ni	Cr	Mo
2340	0·39	0·78	3·37	—	—
3140	0·40	0·76	1·37	0·66	—
4140	0·38	0·80	—	1·00	0·19
4340	0·41	0·84	1·73	0·84	0·24
4340	0·40	0·80	1·76	0·84	0·25
5145	0·49	0·85	0·18	0·89	0·03

They were treated in the following way :—

(1) *Austenitised Forty-Four to Sixty Hours in Hydrogen at* 1120 *deg. Cent.*—Quenched in salt bath for isothermal transformation and held for various periods of time, followed by water quenching. Room temperature aged one week before sectioning.

(2) *Austenitised Sixty Hours in Hydrogen at* 1120 *deg. Cent.*—End-quenched in standard end-quenching hardenability apparatus modified to hold larger specimens. Cooled to room temperature and aged one month before sectioning.

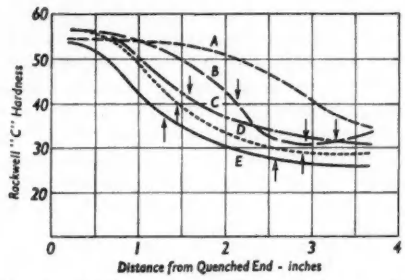
* *Journal of Metals*, August, 1955, page 895.

(3) *Austenitised Twenty to Sixty Hours in Hydrogen or Nitrogen at* 1120 *deg. Cent.* — Quenched directly in water and aged at room temperature before sectioning.

The specimens, which were about 1½in diameter and 2½in long (or 4in long for end-quenching) were sectioned in an abrasive cut-off machine while submerged in water. They were macro-etched with 30 per cent hydrochloric acid or electropolished in a liquid consisting of 25 per cent saturated aqueous solution of lithium nitrate and 75 per cent methyl alcohol. No flakes or cracks of any kind were observed until after the specimens had been aged at room temperature. No flakes were observed in steels austenitised in nitrogen. The presence of hydrogen appeared to be essential.

END-QUENCH TESTS

The most novel feature of the work was the use of the end-quenching equipment to give specimens of varying hardness and microstructure along the length of the bar. The bars were sectioned after ageing, hardness measurements made and the microstructure examined. An indication of the regions in which hair-line cracks occurred is given by the arrows in Fig. 1.



Curve *A*, steel 4340 (no flaking) ; *B*, 2340 ; *C*, 4140 ; *D*, 5145 ; *E*, 3140.

Fig. 1—Hardness curves. Position of start and end of flaking shown by arrows

The microstructures in these regions consisted of martensite and bainite. Hair-line cracks were not observed when the martensite was more than 30 per cent of the total. The amount of austenite transformed to bainite had to reach at least 70 per cent before cracks were formed. A similar conclusion held for the isothermal transformations. For example, steel 4340 transformed at 338 deg. Cent. for six minutes consisted of martensite and bainite and showed hair-line cracks. Transformed at the same temperature for twenty-two minutes it consisted of bainite only and showed no cracks. In every case in which transformation was complete above the M_s temperature flakes did not appear "regardless of the hydrogen content." (The highest hydrogen in a non-flaked bar was 7·7 cubic centimetres per 100 g.)

CONCLUSIONS

The authors state their conclusions in the following words :—

"(1) Hydrogen in the steel is necessary for flake formation.

"(2) Transformation stresses must be present. Flaking does not occur if the decomposition of austenite is completed above M_s prior to cooling to room temperature.

"(3) Under appropriate conditions abnormally high hydrogen contents may be tolerated without flaking.

"(4) The greatest tendency to flake formation exists in mixed structures containing relatively small amounts of martensite.

"(5) There is no correlation between flake formation in such mixed structures (with small amount of martensite) and the average hydrogen content.

"(6) Predominantly martensitic structures exhibit radial or quench type cracks which bear a relationship to specimen geometry. Cooling stresses undoubtedly play an important role along with stresses from transformations and average hydrogen content."

Whereas some would claim that hydrogen pressure, without any other source of stress, will produce hair-line cracks, these authors, while agreeing that the presence of hydrogen is essential, found (in the special circumstances of their experiments) that flakes did not form in the absence of transformation stresses.

Fortunately, as already mentioned, the thermal precautionary treatment against hair-line cracks remains effective whichever view is held of their origin.

Surface Hardening

SURFACE hardening by rapid heating and quenching of the surface of a steel of good hardenability is frequently more economical than case hardening by carburising, nitriding or other methods of producing a diffusion coating. The method was long ago applied to gear teeth and other surfaces that had to resist wear, but in recent years equipment has been devised for heating by gas flames or electrical induction methods under closely controlled conditions. The relative merits of gas heating and induction heating are discussed by W. S. Hyler and H. J. Grover* on the basis of work they have carried out at the Battelle Memorial Institute. The essential differences in the hardened regions produced by these methods are due to differences in rate of heat input to the surface. This rate must always be greater than the rate of heat transfer from the surface to the interior, and the steeper the temperature gradient the more shallow will be the depth of the hardened zone. An air-coal gas flame from a metallic burner will not, as a rule, give a sufficiently high rate of heat input. Ceramic burners are now in use. These provide a small burning chamber in which complete combustion of the gas occurs. The incandescent gases are discharged from the burner with velocities up to 1400ft per second and impinge on the surface to be hardened. A temperature control system warns the operator when the surface of the rotating steel part reaches a predetermined temperature, and the workpiece is then plunged into the quenching tank situated below the heating unit. The minimum depth of hardened case obtainable with a ceramic burner installation is about 0·125in.

With oxy-acetylene burners the rate of heat input is greater. A radiation device measures the surface temperature and when a prearranged temperature is reached the gas is shut off and the workpiece enters the quenching medium on a conveyor. The minimum depth of hardened case obtainable by the oxy-acetylene process is 0·060in. The operation can be made fully automatic, as also can induction heating installations, in which the rate of heat input is very high, thus producing a very steep temperature gradient and a correspondingly shallow hardened zone.

For the same current density an increase in frequency increases the thermal gradient and so decreases the depth of hardening in the following way :—

Frequency, c/s	Minimum depth of hardened zone, in
3,000	0·060
9,600	0·040
500,000	0·020
1,000,000	0·010

Tests were made at the Battelle Memorial Institute to compare the metallurgical character of the hardened zones produced by oxy-acetylene gas and by induction heating. It was found that an increase in case depth to 0·225in (by gas heating) did not cause detectable distortion. Gas heating generally resulted in coarser grain size, but this had no significant effect on the mechanical properties of the case. Provided that the case depths were the same, mechanical tests (including fatigue) did not show any difference in quality. Except in the surface hardening of thin-walled parts, there was no particular merit in a very shallow hardened zone. The hardness of the surface showed more scatter when the depth of the hardened zone was less than 0·130in. Gears hardened by oxy-acetylene and by induction methods, and tested under simulated service conditions, had essentially the same surface fatigue characteristics.

There were no special metallurgical reasons for preferring one method rather than the other. Because it is capable of producing such a shallow hardened skin, induction heating is the more suitable for very thin-walled parts. Otherwise the choice between the oxy-acetylene and induction heating processes must depend on economic considerations.

* Materials and Methods, August 1955, page 103.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

MINERAL PROSPECTING BY DIVINATION

SIR,—I notice that recent articles in your journal on geophysical prospecting were followed by some correspondence on divination, but I cannot understand why those who describe themselves as dowsers or diviners do not use their allegedly divine gifts to benefit mankind and thus reap with honour the rich rewards which surely await them if their characters are reliable, their gifts are real and their statements are true. Why should mining prospectors live hard and toiling lives when they could so easily ask Mr. A. to bring his divining rod along and find without trouble alluvial gold, copper ore in bulk or the most valuable mineral of all, water ?

I have lived among mining prospectors, but I have never yet met one who earned his living by any other way than by acute observation, basic scientific knowledge and common sense. I do know that no reputable mining company obtains its finance by basing its prospectus on diviner's statements, and no water company raises its capital other than by using the most reliable data on rainfall or river flow. Thus belief in the alleged gift of divining is not confirmed by commercial venturers. Why, then, does this belief persist so strongly in others ? Is it because people are lazy ? And if there is " something in it," as so many assert, why do they not try and find the something ? If one examines a large enough sample of diviners' statements, one finds that it does not matter what the rod is made of, how it is gripped or what the indicating force or motion is, if any. The statements contradict each other. So there is nothing much to rely upon except perhaps that a forked shape for the divining rod when it is used is most common and is universal. Water is by far the most common claim. Valuable minerals come next, trailing off to many other objects. To sum up, diviners claim to do anything which is difficult and costly very cheaply—in other words, to provide short cuts to knowledge.

We are safer if we limit ourselves to consider the finding of water. Those who have lived (as I have done) in a desert, know that life is dependent on water and for this reason water is the most valuable mineral of all. The need for it has lasted from the earliest dawn of human history and will last until the last human being is dead. This period is a close approximation to Eternity, and Eternity can be measured by time. That our thinking ancestors did measure time by rainfall is proved by the fact that its name is derived from the Greek word " *temno*," which means " I cut," i.e. time is a piece of Eternity cut off. It was cut off or measured by the annual recurrence of rainfall after a dry season just as time is measured in India nowadays by the interval between monsoons. Such recurrent events which brought water and crops and, therefore, an ensuing year's renewed life, were not only well remembered for themselves, but memory was emphasised by the display of lightning from which the rainfall was inseparable. When in dire need of water, men have asked God to send them some. This was done in those early days (as it is done now by primitive people all over the world) by bluntly telling God by example what to do. The ground was dowsed by sprinkling it with water or the forked twig (shaped like a lightning flash) was waved about. Dowsing and (water) divining are thus synonymous words. Even rain makers of the present day are buried with forked twigs as memorials at their feet. Have your readers ever thought why in several languages, such as French and Spanish, there is only one word, e.g. *le temps* or *el tiempo*, for time, tempest, storm and wind ? The reason is that time was measured by the annually recurrent storms that brought rainfall. This has come down to us from the early ages.

I am not impressed by men's honesty in past ages. An observant and astute man, having noted the distant lightning, could easily persuade his fellows that he could produce water by foretelling the onset of the storm. From that to thinking he was as knowledgeable as God was not such a great step, and if he could find water why not other valuable things ? Expense was so easily saved by believing what he said, and it brought much *kudos*. I was told when I lived in Chile that an improvident absconding thief was invariably found at the end of his tether with his fingers' ends worn away in searching for water. I have not seen this, but it is a good example of the desire to continue to live. My opinion is that water divining is a survival, deeply engrained and apparently ineradicable, of man's intense desire to retain and sustain the life he has been given.

JOHN F. SHIPLEY

September 26th.

THE SCHWEBEBAHN

SIR,—We have read with great interest the letter of Mr. E. B. Parker, on the Langen Suspension Railway, which appeared in your issue of August 5th. We would thank you for your footnote, and would take this opportunity of also thanking Mr. Parker for his full and interesting description of the railway, the technical facts of which are all correct. We were pleased to see from your footnote that you confirmed that the Schwebebahn is still sound in construction and working well. The railway has now been in continuous operation for close upon 55 years, and so far as its present state may allow a prophecy to be made, it seems likely we think that it will run for at least another 50 years, without showing detrimental damage. This unusual means of transport has come to be looked upon, not only in Germany, but by many interested engineers abroad, as perhaps forming the most reliable means of transport which up to the present has existed. Since its earliest days the Schwebebahn has not suffered a single loss by death of the many passengers it has carried. With regard to Mr. Parker's suggestion that perhaps the painting of the lattice steel " A " frames and the girders supporting the track, may have presented difficulties, this has not been borne out in actual fact. Every five or six years all the structural members are carefully freed from rust and then painted, a practice which has presented no difficulty and has given every satisfaction. On March 1st, 1951, the Schwebebahn celebrated its fiftieth anniversary and its Jubilee. To mark that occasion a small booklet was published giving particulars of the construction of the railway and its working along with many interesting photographs and some humorous drawings.

WUPPERTAL STADTWERKE, A.G.
Verwaltungshaus,
(22a), Wuppertal-Barmen.
September 2nd.

Literature

The Railway Engineers. By O. S. NOCK. London : B. T. Batsford, Ltd., 4, Fitzhardinge Street, Portman Square, W.1. Price 18s.

IN his lecture to the Newcomen Society, presented at King's College, Newcastle upon Tyne, on June 7th last, Professor Aubrey F. Burstall took for his subject " Study of Engineering History," the concluding paragraph of which read as follows :—

" In conclusion I should like to add that in my own view the greatest value of the study of engineering history is not to be found in observing its logical consequences, but in something intangible that is hard to express. To study and appreciate the achievements of the past is constantly to receive enlightenment without frustration and to feel awe and wonder from time to time as what one does is to share with one's students a refreshment of the human spirit."

Truly, to read this new book reciting the work accomplished by the first railway engineers excites both awe and wonder when we realise how much was achieved with so little. Within the compass of a relatively small volume extending over but 256 pages, the author has contrived to present a historical sketch of the early development of our railway system, explaining how formidable problems of bridge building, the construction of viaducts and track laying were dealt with and numerous difficulties overcome. The story of the construction of the first locomotives and their authors is also told and, while much of this is tolerably well known, it, even so, makes interesting and refreshing reading. The book has been divided into five chapters, named respectively, " The Prelude to Railways," " Building the First Main Lines," " Locomotives and Locomotive Men," " Some Great Constructional Works " and, finally, " Running the Trains." To support the text, there are in all sixty-five illustrations, many of which are of exceptional interest; perhaps more especially is this the case of those illustrating works in the actual construction of our railways which include many of the famous bridges engineered and built in a now remote past and, in many instances, to this day standing tributes to their originators.

In writing, the author has evidently been

fortunate in having access to an extensive library if we are to judge by the bibliographical references listed on page 8, while, as already remarked, the interesting illustrations show that he has been equally fortunate. Taken as a whole, the book is well arranged and printed. In Chapter 1 the author naturally deals with the beginning of things, mentioning Newcomen, Watt, Boulton, Trevithick and, last but not least, the Stephensons, George and his son Robert. "Building the First Main Lines" includes a graphic account of the construction of the Liverpool and Manchester line, the story of Chat Moss being retold, as is also the extraordinary proposal put forward (not by Stephenson), for the use of cable haulage in lieu of steam locomotives, for which purpose it was suggested that the line might be divided into sections each with its stationary hauling engines and boiler plant. The trains, it seems, were to be passed on from one set of cables to the next on their journey. While this was unquestionably a fantastic idea for the purpose then suggested, it was nevertheless given expression to when, many years later, cable-operated tramways enjoyed a certain amount of favour. In any event it was possibly more worthy of notice than the so-called Atmospheric System, well described in the third chapter, which, strange to say, received the support and blessing of no less a person than Brunel. However, when tried, the affair was an utter failure and one which Robert Stephenson stood out against in splendid isolation amongst otherwise able engineers of that day. This chapter, perhaps one of the most interesting, includes much concerning the early locomotives and locomotive men, Hackworth and his engine "Royal George" and the ill-fated "Sans Pareil," which took part in the remarkable Rainhill trials in company with Robert Stephenson's engine, "The Rocket," which was awarded by the judges the prize for the best locomotive. The author naturally gives this masterpiece in locomotive engineering considerable notice, and those who may desire to know still more may be referred to THE ENGINEER of May 31, 1929, when a description appeared, together with drawings of a replica of the original engine as built by Robert Stephenson and Co. for Henry Ford's Museum at Detroit, U.S.A.

When discussing the "Rocket," the author mentions the blast pipe arrangement as fitted to this engine; reference to these drawings will supply the answer. In fact there were two, one for each cylinder exhausting into the chimney which, with its height above the rails of 15ft, was one of the more important blessings bestowed on the railways by this remarkable engine—it fixed the height of overbridges! One thinks of the "Rocket" as being the prototype of the modern locomotive, but although this engine had the first multitubular boiler, the engine "Northumbrian" of 1830, also built by R. Stephenson, was the first to have the locomotive type boiler as we now know it embracing an internal rectangular firebox, flue tubes and a smokebox with blast pipe and chimney arrangement common to this day.

As the author says, the outcome of the Rainhill trials gave a "tremendous fillip" to railways, and from that time onwards a new race of men was born—locomotive men—and with them the locomotive manufacturing industry came into being, headed, in the first instance, by Robert Stephenson and Co. at Newcastle upon Tyne.

Other names now appear: for instance, John Ramsbottom, who was associated with Sharp Roberts of Manchester, Alexander Allen, who at one time was with Stephenson and Co.; others which should be mentioned are Crampton, Daniel Gooch, Robert Sinclair, also Archibald Sturrock at Swindon and, later, on the old Great Northern. In this same chapter we are told much about the great controversy that arose concerning the question of the rail gauge—the "narrow" versus the "broad" 7ft gauge adopted by Brunel for the Great Western while Stephenson, Lock and Nicholas Wood stood fast by the "narrow" 4ft 8½in gauge.

Of John Ramsbottom, "perhaps the greatest locomotive man of mid-Victorian times," the author has much to say and recalls how standardisation became the "watch word" at Crewe, where Ramsbottom built for the London and North Western no fewer than 943 standard six-coupled goods engines to the same set of drawings.

When we come to Chapter 4, an interesting account of the construction of the High Level Bridge over the Tyne at Newcastle claims attention. This, like the Royal Border Bridge at Berwick, was the work of R. Stephenson. Then there is the first Woodhead Tunnel under the Pennines on the Manchester and Sheffield line, engineered by Joseph Lock, who was also responsible for the Lancaster and Carlisle line and, therefore, incidentally for the well-known Shap "incline." Passing on to further works carried out by Robert Stephenson, one that claims special recognition is the building of the Chester and Holyhead Line, involving the construction of the tubular bridges at Conway and across the Menai Strait, the latter being the wonderful Britannia bridge, which, like the one at Conway, is roughly parallel to Telford's suspension bridge. The construction of the Britannia bridge, together with the building of that equally remarkable example of railway engineering, the London and Birmingham line, is possibly of all Stephenson's works the most outstanding. The latter, it may be remarked, takes in such works as the heart-breaking job of boring the Kilsby tunnel and digging out the Tring cutting; however, the resulting line with its ruling grade of 1 in 330 has been acclaimed as being one of the finest roads in the world.

Another engineering triumph—this time by Brunel—is the bridge over the Tamar at Saltash—the Royal Albert bridge, opened by the Prince Consort in 1839. The final chapter, which has for its subject "Running the Trains," commences with a descriptive account of the opening of the Liverpool and Manchester line and concludes with references to the genesis of railway signalling and the automatic air and vacuum brakes, touching on the early work of John Saxby, a household name in the development of railway signalling, and mentions also Armstrong's work at Swindon on the improvement of the automatic vacuum brake. Throughout this book we are brought face to face with many famous men responsible in varying degrees for carrying out engineering projects of astonishing magnitude, often with no previous experience to guide them, and usually with but scanty equipment. Yet their works remain to this day standing as everlasting monumental tributes to the engineering skill of far-seeing men and, as such, inevitably brings to mind Longfellow's words when writing,

> "Lives of great men all remind us,
> We can make our lives sublime;
> And departing leave behind us
> Footprints on the sands of time."

Truly these "great men" of yesterday have left their names imprinted on the world's railways of to-day as constant reminders of their skill and daring.

Analysis of Statically Indeterminate Structures. By J. I. PARCEL and R. B. B. MOORMAN. New York: John Wiley and Sons, Inc.; London: Chapman and Hall, Ltd. 37, Essex Street, W.C.2. Price 76s.

ONE of the characteristics of modern technical education is that it tends to provide short-cut solutions for stereotyped problems. There can be no doubt, however, that it provides quick returns for educational investment—the designer who goes into a structural engineering office can, in a very short time, be set to work out stresses, scantlings or schedules for reinforcing bars. In a matter of weeks he can earn his keep and justify his presence. The system obviously has attractions for both employee and employer. Difficulties arise when a design problem turns up for which there is no ready-made answer. When this occurs what usually happens is that the problem is given to a specialist who understands the fundamental principles of structural theory and who can think up a tailor-made solution. No greater tribute can be paid to the book than to say that it is calculated to produce just this type of man.

Analysis of Statically Indeterminate Structures is a very complete and thoroughly good treatise on the subject. It follows the chronological development of the science, establishing the concepts and solutions of Castigliano, Maxwell and Mohr. Continuous beams and multiple frames are analysed in very considerable detail by the three-moment and slope-deflection methods before they are tackled by the method of moment distribution. Here the authors have put forward a refinement to the Hardy Cross method in which sidesway takes place automatically as joints are balanced in the normal rotation process. An extension to the classic slope-deflection equations is developed to deal with frames with curved members. The rarely studied case of continuous spans on elastic supports is very adequately dealt with. The theory of elastic weights is treated in much greater detail than is usual in books in the English language and considerably more space is devoted to suspension bridges than is customary. A feature of the book is the graphical solutions of problems drawn on inset sheets which will give the reader a far better idea of how a problem is dealt with in a design office than the sketches which are to be found in many manuals.

The book, it should be mentioned, is to be followed by a second volume treating such specialised subjects as very tall building frames, dynamic oscillations of suspension bridges, and shell structures. When so many indifferent books are produced to-day on the theory of structures, it is indeed pleasing to be able to be unreservedly complimentary about this one.

Books Received

Basic Sheet-Metal Practice. By J. W. Giachino. London: Macmillan and Co., Ltd., St. Martin's Street, W.C.2. Price 28s.

Principles of Helicopter Engineering. By Jacob Shapiro. London: Temple Press, Ltd., Bowling Green Lane, E.C.1. Price 55s.

Teach Yourself Perspective Drawing. By H. F. Hollis. London: The English Universities Press, Ltd., 102, Newgate Street, E.C.1. Price 6s.

The Gas Turbine Manual. Second edition. By R. J. Welsh and Geoffrey Waller. London: Temple Press, Ltd., Bowling Green Lane, E.C.1. Price 30s.

The Physical Society Reports on Progress in Physics. Volume XVIII (1955). London: The Physical Society, 1, Lowther Gardens, Prince Consort Road, S.W.7. Price 50s.

Ahmedabad "C" Generating Station

Three 15MW turbo-alternators and the associated boilers and auxiliaries make up the recently completed first stage development of the "C" station owned and operated by the Ahmedabad Electricity Company, Ltd., India. It supplies power to Ahmedabad, an industrial city with cotton mills and a population of 850,000. *The company has more than quadrupled its sales of electricity within the past nine years, and the new station has an annual load factor of about* 62 *per cent, the load factor for a "normal day" being about* 70 *per cent. The following description of the new station is based on information supplied by the consulting engineers, Messrs. S. J. W. Baldwin, M.I.E.E., and W. U. White, M.I.E.E.*

THE Ahmedabad Electricity Company, Ltd., serves the city of Ahmedabad, which is some 300 miles north of Bombay, and has a population of about 850,000 inhabitants, the principal industry being in cotton mills. It was not until 1934 that the company was able to cater seriously for the large potential industrial load. At about that time the original diesel generating station was gradually taken out of use, and generation by steam prime movers introduced. Thereafter the expansion of the company's system has been rapid and continuous. The original "A" station of 37·5MW was fully loaded by 1940 and the construction of the "B" station of 60MW was started, as circumstances permitted, during the 1939–45 war. Since then the growing demand for power has necessitated the construction of the "C" station, designed for an ultimate capacity of 120MW, of which 45MW has now been brought into service. An indication of the very rapid growth of load is that the energy sales have increased very nearly four-fold during the past decade, from some 110 million units in 1945 to 428 million units in 1954. The company's power plant is also the source of supply to the Bombay Government's North Gujerat grid scheme which has contributed to the increase in energy sales over the last few years.

Developments which the company has undertaken in the past twenty years are tabulated below :

Development of Generating Stations at Ahmedabad

	"A" station	"B" station	"C" station
Date of commissioning ...	1934	1947	1954
Designed capacity, MW...	37·5	60	120 (ultimate)
Installed capacity, MW ..	37·5	60	45
Turbo-alternator sets, MW	2×3·75 4×7·5	4×15·0	3×15·0
Number of boilers	9	8	4
Capacity, lb/hr	45,000	105,000	170,000
Pressure, lb/sq in... ...	250	450	625
Total temperature, deg. Fah.	750	800	850
Coal storage	In silos under water		Consolidated open stock-piles
Coal handling	By telphers		By belt conveyors

Because of the post-war shortage of fabricated steelwork, it was decided that the building should be entirely of reinforced concrete construction, as the reinforcement steel could be provided from Indian sources and the whole of the work could be done by local contractors with local labour. The structure housing the projected 120MW of plant has been erected and has proved to be cheaper in first cost than a steel-framed building of similar dimensions. It has a total length of 428ft and a width of 160ft. In cross section the building is divided into three sections, the two outer sections comprising the boiler house and turbine hall, whilst the central section contains, at various levels, the boiler feed pump bay, station control room, auxiliary power transformers and switchgear, and 500-ton boiler bunkers, raw water and surge tanks, and coal shuttle conveyor.

An interesting aspect of the building is that the roof is of shell construction ; the span of the turbine room is 62ft 6in and of the boiler room 64ft 6in, and the thickness of concrete of the roof does not exceed 3in at mid-span. The cladding of the building was carried out by means of precast sections, only 2½in thick, and this was a major factor in the ease and rapidity of construction. Two concrete chimneys have been provided at present, each dealing with the discharge gases from two boilers. A steel mid-feather is installed at the bottom of each chimney to prevent undesirable turbulence from the entry of gases from each i.d. fan, and a refractory brick lining is provided as protection from the temperature of the gases. Facilities have been introduced at the base of the chimney to enable fly ash to be removed and discharged direct into trucks or wagons for dispersal at the ash dump. Because of the high ambient temperatures, special attention has been paid to the ventilation of the building. On the turbine hall side of the structure large vertical sunshades have been provided to cast shadows on the main windows and walls (background, Fig. 4), and the boiler house external walls are provided with large louvres (Fig. 1), behind which expanded metal screens prevent birds from entering the building. Roof ventilation is by means of louvred openings, as can be seen from Fig. 1.

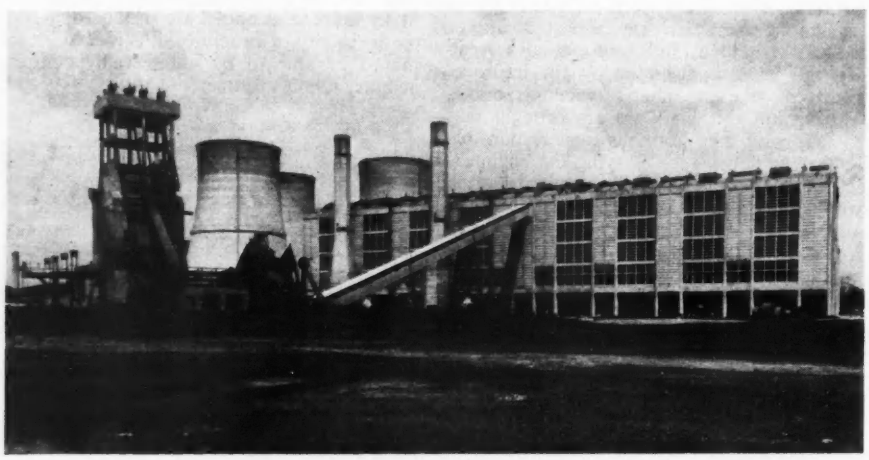


Fig. 1—Ahmedabad "C" power station is designed for an ultimate capacity of 120MW, of which 45MW is at present installed. This view shows the shell construction of the boiler-house roof and the louvred ventilation openings in the roof and walls

Coal Handling Plant

About 25 per cent of the station's coal requirements are delivered by rail in closed wagons. An "End-Rock" tippler, designed to handle 200 tons of coal per hour, has been installed. This tippler (Fig. 2) inverts the coal wagons and enables the wagons to be rocked endwise to free the coal lodged in the end portions of the wagons, and discharge it through the central doors. The tippler also incorporates a weigh-bridge and automatic weight-printing mechanism.

Handling of the full and empty wagons is done by the installation of Strachan and Henshaw, Ltd.'s "Beetle" hauling equipment. It consists, briefly, of a flat, box-like carriage mounted on skids between rail tracks and having retractable arms. It is capable of moving backwards and forwards through a distance of about two wagon lengths. The retractable arms terminate in three rollers in triangular formation, one of which presses on the tyres of the wagon wheels, and moves the wagons forward, while the others rest on the rail tracks (Fig. 2). On the return travel the arms are retracted and freely pass beneath the wagons to pick up the next batch of wagons to be moved forward.

In operation the leading coal wagon is manually uncoupled from the rest of the train—up

Fig. 2—Coal crusher house and "end-rock" tippler. The "Beetle" train marshalling equipment can be seen in the lower left-hand corner

to fourteen wagons are placed at a time—and then moved on to the tippler by the "Beetle," which simultaneously brings the remainder of the train one wagon length forward to the tippler. After tipping and weighing the now empty wagon is edged off the tippler by the next incoming movement of the "Beetle" and passes, by gravity, down a short incline to the out-haul "Beetle," which then marshals the train of empties.

With one man to uncouple and recouple the wagons the rest of the operation of handling the full and empty wagons is controlled by the man who operates the tippler itself. In effect the shunting locomotive, having delivered the full train of wagons to the "Beetle," is freed for other duties until it is called upon to remove the reassembled train of empties.

In other respects the coal handling plant follows normal practice. After being crushed the coal passes to a short shuttle conveyor, from which it can be discharged either to the stockpile, or to the main inclined belt conveyor for delivery to the bunker room in the station building. In the bunker room the coal is transferred to a shuttle conveyor, whence it is discharged as required to each of the 500-ton bunkers serving each boiler.

Provision is made for thorough wetting of the

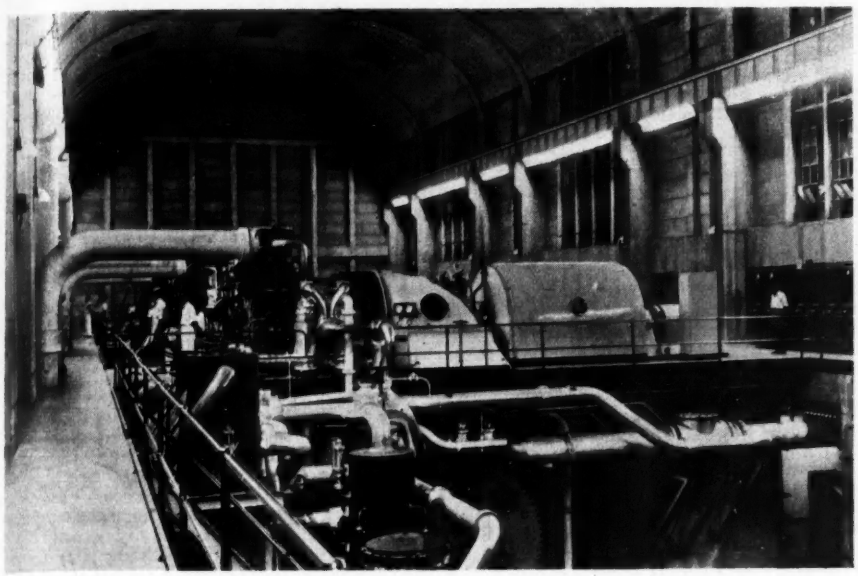


Fig. 3—Turbine hall, showing one of the three 15MW sets installed in Ahmedabad "C" generating station. The building is of reinforced concrete construction with shell roofs

coal, an important operation because all surface moisture has been dried out of the coal long before its delivery, and because the coals used have low inherent moisture content. It is also necessary to bind together the large percentage of "fines" which are contained in the coal. The procedure is to give the coals a preliminary wetting by water sprays at the time of tipping wagons. A second wetting is given on the shuttle conveyor on discharge from the crushers, and a final controlled wetting is provided at the bottom of the main inclined belt conveyor *en route* to the bunker room.

Ash disposal is by conventional methods, the hot ash being extracted from the boilers and quenched by means of paddle ash extractors. It is discharged on to a belt conveyor and taken to a pit where it is elevated into a main ash silo by an automatic skip hoist. The ash silo is capable of storing the total ash from a full day's operation, and at convenient times the accumulated ash is drawn off into a special train of side tipping wagons for final disposal on a dumping ground.

Because of the danger of spontaneous combustion stockpiling is normally limited to 3ft in depth. In the past the company has made a practice of holding stock coal in large silos and immersed in water, which has proved to be effective, especially for coal conditioning; but the installation is expensive, and does not lend itself to convenient recovery except by means of a travelling telpher equipment. To avoid this difficulty, a large bulldozer is employed to spread the coal over a large area, and by virtue of its weight to consolidate the stockpile. This consolidation reduces the voids in the pile and inhibits self-combustion. It has been found that the depth of stockpiles can be increased to some 5ft to 6ft without harm, and experiments are continuing to ascertain the maximum depth which can be safely used. It may be noted that the bulldozer is fitted with large rubber tyres to improve consolidation.

A point of some interest is that all coal delivered to the station comes from fields at least 700 miles distant; some comes from as far away as Bengal, 1200 miles away. In spite of the long haulage involved the price delivered on site at about £2 12s. 6d. per ton compares very favourably with the corresponding price ruling in the U.K. The price is, however, treble what it was before 1939.

Boiler Plant

The installation now in service comprises four units, each having an M.C.R. of 170,000 lb per hour at 625 lb per square inch gauge, and 850 deg. Fah. The boilers are tri-drum units with water-cooled walls, and twin louvre-type "Underfeed" stokers designed to burn the low-grade coals received at the station. Pendant type superheaters are installed and temperatures are regulated by motor-operated dampers. Combustion air to the f.d. fan is taken from the central bay of the building and, by extracting air from this area and from the turbine hall, greatly promotes the ventilation of the building. On discharge from the f.d. fan the air is pre-heated, a portion passing on to the secondary air fan and the balance direct to the boiler, as is usual. Boiler instrumentation and control conform to modern practice, and provision is made for chemical dosing to regulate the pH value of the water, and for sampling points for oxygen content control. The outlet steam from the boilers is controlled by motor-operated valves and collected in a bus main, whence it is taken to independent separators to serve each turbo-alternator. The boiler feed-water arrangements include four electrically driven feed pumps, and one steam-turbo-pump as essential standby, the pumps being connected between the first and second stages of the feed-heating equipment.

Water Supply

Although the station is situated on the bank of the Sabarmati River—about 500 yards wide at this point—it has not been practicable to use the river water because, during the dry season, the surface water is reduced to a small channel which shifts from time to time on account of the scouring which occurs when the river is in spate. Fortunately, ample subsoil water is available and the entire requirements of the "A," "B" and "C" stations for all purposes are obtained from a number of wells distributed over the site. The average yield of the wells is 25,000 gallons per hour each. The raw water used for boiler make-up purposes is passed through low-pressure evaporators, no other treatment being necessary to make the water suitable for this purpose.

Cooling Towers

The present installation at "C" station consists of three concrete hyperbolic towers, in clover-leaf formation near one end of the building; three more towers will be added at the opposite end of the building when required. Each tower is capable of dealing with the circulating water from 20MW of plant, and cools the water 12 deg. Fah. from 107 deg. to 95 deg. Fah. under the worst atmospheric conditions experienced. The towers are 200ft in diameter at the base and 200ft high, the height being determined by the proximity of Ahmedabad Airport. A feature of the towers is that the louvres and supports are all of concrete, the former being prestressed to provide strength and rigidity. Chlorination of the water is applied as a means of algæ control. All water in circulation is also treated with "Calgon" to inhibit the accumulation of deposits in the condensers. Undesirable concentration of salts is regulated by appropriate leak-off and the hardness (all temporary) of the water is not allowed to exceed 18 deg.

Turbo-Alternator Plant

Three 15MW units are now installed (Fig. 3), generating at 11kV, and each is solidly coupled to an 18·75MVA step-up transformer and thence to a 66kV switchyard.

Three-stage feed heating is provided, giving a final feed temperature of 300 deg. Fah., and bled-steam, low-pressure evaporators deal with raw water make-up to the boilers. The circulating water for the condensers is received from a bus main, and is taken off to serve individual machines, thus enabling any c.w. pump to be used, as required. Alternator cooling is effected by closed-circuit air coolers, and the temperature rise of the machines is 10 deg. Cent. less than under B.S.S. allowances.

Control Room

This room is situated in the central "bay" of the building, and midway along its length.

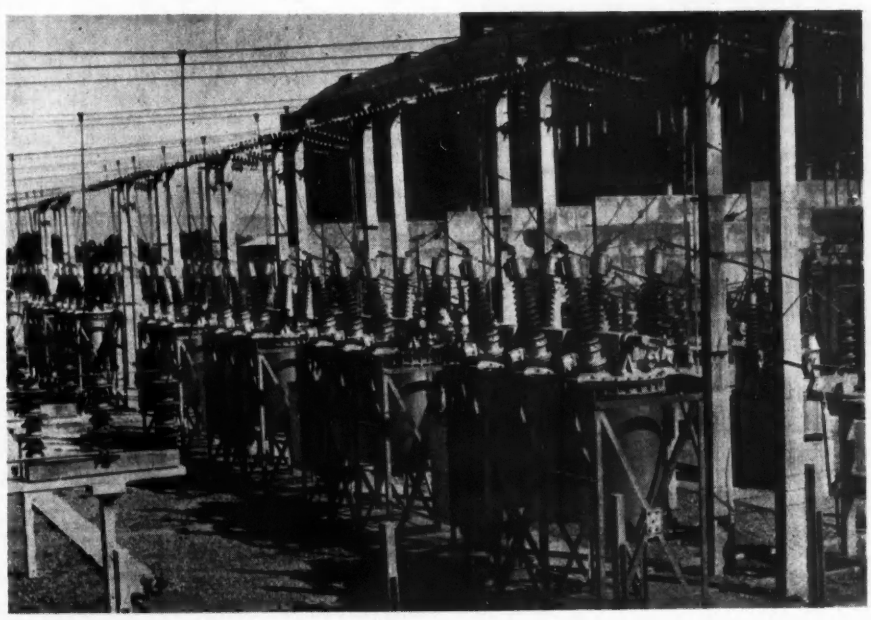


Fig. 4—66kV outdoor switching station. The sunshades over the windows in the walls of the building can be seen in the background

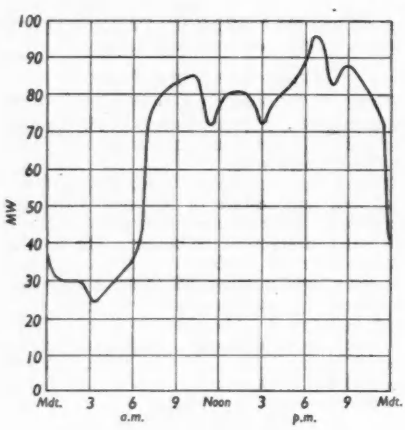
This position commands visual observation of the turbine hall and of the boiler firing aisle. Besides the main 66kV circuits in the external switchyard, all supplies for auxiliary power are controlled from this point, the low-tension transformers and switchgear for the auxiliaries being contained in rooms adjoining the control room. Aluminium sheathed cables are used extensively for auxiliary power supplies and for control circuits, mainly because of the shortage of lead.

66kV Switchyard

The design and layout of the switchyard (Fig. 4) is orthodox, all transformers and switchgear being for outdoor use. The circuit breakers have a rupturing capacity of 1000MVA each and are pneumatically operated, by remote control from the control room, with provision for local operation where required. Provision is made for four outgoing 30MVA overhead transmission lines (two circuits are now in use) and two interconnectors of 18·75MVA each to tie this station in with the "A" and "B" stations. All oil used in transformers and switchgear is piped to a central point for cleaning and reconditioning.

66kV Transmission and Substations

Until this new station was built the primary distribution of energy was by cables at 11kV. Further development of this system was found to be uneconomic, and some 12 route miles of 66kV transmission by overhead lines have been



Units generated, $1·58 \times 10^8$.
Load factor, 68·7 per cent.

Fig. 5—Load curve for December 7, 1954, on the system of the Ahmedabad Electricity Company, Ltd.

installed, serving three (ultimately four) outdoor substations. Each substation is rated for 12·5MVA at present, but can be expanded to double this capacity when necessary. The output is stepped down to 11kV and, besides serving new consumers, picks up load transferred from overloaded sections of the existing network, and through tie-lines ensures flexibility and interchangeability between the old and the new 11kV systems. This arrangement allows continued expansion in congested areas without resorting to extensive reinforcement and laying new cables in those areas.

Load Factor

The high load factor of this station is a matter of interest. In some measure at least it is the result of the tariff schedules which the company has developed, and which are simple and readily understood both by the ordinary domestic consumer and the specialised industrial consumer. A typical load curve is illustrated in Fig. 5; the load factor for a normal day is of the order of 70 per cent, the annual load factor being about 62 per cent in spite of the large number of holidays, compared with the U.K., for religious festivals and other national occasions.

Principal Contractors

Power station building, cooling towers, foundations and all civil engineering works, Gammon India, Ltd.; turbo-alternators, condensers, feed heaters and evaporators, main and auxiliary switchgear, transformers, control room, relays and metering, The British Thomson-Houston Company, Ltd.; boilers, stokers, feed-pumps, steam and water piping, chemical dosing plant, International Combustion, Ltd.; coal and ash-handling plant, "end-rock" tippler, "Beetle" haulage, Strachan and Henshaw, Ltd.; 66kV transmission, aluminium sheathed cables for auxiliary supplies, control cables, British Insulated Callender's Cables, Ltd.

Annual Report of the British Electricity Authority, 1954-55

THE seventh annual report, covering the activities of the British Electricity Authority during the year ended March 31, 1955, was published earlier this week, and is summarised below. As from April 1, 1955, under the Electricity Reorganisation (Scotland) Act, 1954, the Authority's undertakings in South Scotland and the undertakings of the South East Scotland and South West Scotland Boards, vested in a new public body called the South of Scotland Electricity Board, and the title of the British Electricity Authority, was changed to Central Electricity Authority.

Electricity Consumption

Consumers purchased more than 62,400 million units of electricity from the Authority and the Area Boards in 1954–55—that is an increase of 11·8 per cent over the previous year and of 76 per cent in the seven years since vesting day. Over half the sales were to industry, nearly a third to domestic consumers and a seventh to commercial consumers. Industrial consumption was 12·8 per cent more than in the previous year, domestic 10·5 per cent, public lighting 9·2 per cent, commercial 11·0 per cent, and farms 22·4 per cent. At March 31, 1955, the number of electricity consumers exceeded 14,900,000, representing increases of 548,146 in the year, 3,200,000 in the seven years since vesting day, and over 5,000,000 since the end of the pre-war year, 1938.

The continued growth of rural electrification is shown by the fact that during 1954–55 14,796 farms were connected to the electricity supply system, compared with 12,948 in the previous year and 10,584 in 1952–53. It is estimated that at vesting day about 90,375 (32 per cent) of the farms in the territory covered by the fourteen Area Boards were using mains electricity. By March 31, 1955, 167,375 farms (60 per cent) were connected. In the seven years since vesting day the number of farm connections increased by 77,000, or 85 per cent. These new connections averaged 11,000 per year, as compared with 4000 during 1938.

Financial Summary

The Authority and the Area Boards had a net surplus in the year of £8,294,478. This was arrived at after transferring £10,500,000 to supplementary reserves for depreciation of fixed assets. The net surplus is only 2¼ per cent on the year's combined revenues of £366 million and less than half of 1 per cent on the £1795 million invested in fixed assets. In the seven years since vesting day the surpluses, before transfer to reserves, have totalled £60·3 million. Of this total £18·6 million has been placed to taxation reserves, £10·5 million to supplementary depreciation reserves, £21·7 million to general reserves, and the balance of £9·5 million carried forward.

The creation of supplementary depreciation reserves is in accord with the previously declared policy of the Authority and Area Boards of applying surpluses largely in the creation of reserve funds which would be available not only to meet occasional deficiencies, should they arise, but also to assist the financing and replacement of assets. The Authority proposes to make contributions of a somewhat similar order to the new supplementary reserve in future years, wherever possible and practical, and to regard such contributions as a charge on surpluses in priority to transfers to the central reserve fund.

The provision of capital to meet the heavy costs of the industry's programme of development and expansion remains a dominant feature of the Authority's finances. In 1954–55 the total capital requirements of the Authority and the Area Boards amounted to £203 million, which were provided to a considerable extent out of borrowed moneys. For some years the annual capital requirements will be of this order and, with the advent of the more costly nuclear power stations, are likely to rise above the current level. In present economic circumstances it is quite clear that if the industry's financial stability is to be assured it will be necessary to earn larger annual surpluses to provide for a greater degree of self-financing of future capital programmes.

At the end of the year under review the Central Authority had a surplus of £11,576,054, compared with £8,011,727 in 1953–54, and the aggregate surplus of the fourteen Area Boards was £7,218,424, as compared with £5,177,011 in 1953–54.

The average price received for electricity sold for all purposes was 1·370d. per unit, which was slightly below the average for 1953–54 of 1·373d., 20·9 per cent above the average of 1947–48 and 29·9 per cent above that of 1937–38.

The average price received for supplies to domestic users was 1·518d. per unit, compared with 1·532d. in the previous year. For supplies to industry the average price received was 1·149d. per unit, compared with 1·143d. in 1953–54; to farms 1·472d., compared with 1·463d.; to commerce 1·901d., compared with 1·911d.; for traction 1·108d., compared with 1·089d.; and for public lighting 1·392d., compared with 1·393d.

Capital expenditure during the year amounted to £202·91 million—£127·49 million by the Central Authority and £75·42 million by the Area Boards—making the gross value of fixed assets £1794·82 million.

Generating Plant

At March 31, 1955, the Central Authority owned 294 power stations with a total installed generating capacity of 20,172,974MW and a total output capacity, assuming all plant in service, of 18,438MW (nearly 25,000,000 h.p.) Total output capacity has increased by 63·9 per cent since vesting day.

New plant brought into service in 1954–55 gave an additional output capacity of 1539MW, which was nearly twice as much as the highest total for any pre-war year. Taking into account the removal of some old plant to make room for new or because it had become unserviceable or obsolete, and the revision of some plant ratings, the net increase in output capacity was 1534MW.

The Authority plans to increase its generating capacity by over 45 per cent during the six years 1955 to 1960. This represents a net addition of some 8400MW of output capacity from approximately 18,250MW at the end of 1954 to 26,650MW at the end of 1960. To achieve this, some 10,300MW of new plant will be provided and about 1885MW of old plant will be shut down to make way for new plant or because it is no longer usable.

Although a very large amount of new plant is being installed, it is still necessary to keep in operation many generating sets and boilers which are old, small and expensive to operate. In the steam power stations, nearly 20 per cent of the total generating capacity and over 16 per cent of the total steaming capacity is provided by sets and boilers twenty-five or more years old.

Over 73,950 million units of electricity were generated by the power stations during 1954–55—11·9 per cent more than in the previous year, 77 per cent more than in the year before national-

isation, and over three times as much as the comparable production in 1938.

The overall thermal efficiency of the Authority's steam power stations has risen steadily from 20·87 per cent in the pre-vesting year, 1947–48, to 22·72 per cent in 1952–53, 23·40 per cent in 1953–54, and 23·85 per cent in 1954–55. Had the average efficiency remained the same as in the previous year, another 800,000 tons of coal would have been consumed at an extra cost of £2,500,000. If the overall thermal efficiency had remained at the 1947–48 level, the consumption of coal at the power stations in the seven years since vesting day would have been some 17·6 million tons greater and the cost over £53,500,000 more.

The average delivered cost per ton of fuel consumed in the Authority's steam power stations was 3·3 per cent higher than in the previous year. The Authority continued to be the largest individual purchaser of coal in Britain. Fuel consumed in its power stations during 1954–55 amounted to 41,000,000 tons, of which nearly 40,000,000 tons was coal. The total fuel consumption was 9·8 per cent more than in 1953–54; the difference between this percentage increase and the corresponding increase of 11·9 per cent in electricity generated reflects further improvements in efficiency of generation.

Average works costs per unit of electricity sent out from the steam stations, however, increased by only 1·1 per cent from 0·5594d. in 1953–54 to 0·5654d. in 1954–55.

The maximum potential demand on the system occurred on Thursday, January 20, 1955, and amounted to 17,200MW, being 900MW higher than that of the previous winter. The demand actually supplied by the plant available at the time was 16,255MW, the difference of some 950MW representing the estimated amount by which the load was reduced by low frequency and reduction of voltage.

The winter plant/load position was similar to that of the previous winter. The margin of available generating capacity is still precariously small and in abnormal weather conditions interruption of supply to some consumers may still be unavoidable on occasions. In the year under review it was only necessary to cut off supplies to consumers on one occasion, compared with one in 1953–54 and 9 in 1952–53.

Nuclear Generation

In a White Paper (Cmd. 8389), issued in February, 1955, the Government outlined a provisional ten-year nuclear power station building programme. Twelve stations, providing 1500MW to 2000MW, are to be built and brought into commission by 1965 at a total cost of about £300 million.

The construction of the first two stations will be started in 1957, and they will begin to operate in 1960–61. Their design will be based largely on that of the experimental plant at Calder Hall, but technical development should be rapid and some of the new stations may be of fundamentally different design. The design of successive stations will depend on the results of the experimental reactor programme of the A.E.A. (U.K. Atomic Energy Authority) and on the experience gained in building and operating the earlier nuclear power stations. If all goes well (the Authority's annual report suggests) it may be practicable by the early 1970s to increase the rate of construction of nuclear stations to match the total requirements of new generating capacity.

The Central Electricity Authority will be responsible for the construction and operation of the nuclear power stations to be built as part of its system under this ten-year programme. By an agreement reached during the year by the C.E.A. and the A.E.A. regarding their collaboration and respective responsibilities in the carrying out of this programme, the A.E.A. will advise the C.E.A. on nuclear aspects of the programme and will also have certain rights of decision on reactor design. The C.E.A. has set up a nuclear power branch of the chief engineer's department to deal with the specialist nuclear techniques and the implementation of the design and construction of the nuclear power station programme.

The Authority has co-operated with the Ministry of Supply and, since August 1, 1954, with the Atomic Energy Authority in the design of the Calder Hall station, an engineer of the Authority being the deputy resident electrical and mechanical engineer on the construction staff there. Seven other engineers of the Authority are undergoing training courses with the A.E.A.

Oil Fuel

Since vesting day it has been possible, in conjunction with the National Coal Board, to study in detail the long-term pattern of coal supplies and qualities for the generation of electricity. There are now increasing signs that the Board will not be able to meet all the growing demands on production. There is, indeed, a gap between the Authority's estimated future requirements for coal and the Board's ability to supply them. The use of nuclear energy is clearly the long-term solution, but it will not be possible to build nuclear power stations in time to meet the shorter-term requirements for more fuel. Accordingly, the Authority will use oil on a very much larger scale than had hitherto been considered.

During the year it was found possible to negotiate an agreement whereby the new Marchwood power station, near Southampton, will take heavy fuel oil from an adjacent refinery at a price calculated to ensure costs of generation equal to those which would be given by coal. The station is expected to come into commission this year and when completed it will burn about 430,000 tons of fuel oil per year in lieu of some 600,000 tons of coal.

Since the end of the year, two agreements have been reached. The first relates to seven stations, viz. Barking, Brunswick Wharf, Littlebrook and Tilbury, all on the Thames or its estuary, and Poole, Portishead (near Bristol) and Plymouth. The price to be paid for fuel oil to be delivered to the majority of the stations will be such that the cost of fuel will not be greater than with equivalent coal consumption. By 1960 the stations will burn between 2,750,000 and 3,000,000 tons of fuel oil per year, equivalent to over 4,000,000 tons of coal. The second agreement covers a further seven stations, viz. Belvedere (near Erith), Bromborough, Carrington (near Manchester), Cliff Quay (Ipswich), Ince (near Ellesmere Port), South Denes (Yarmouth), and a projected station on the Thames estuary. It provides for oil supplies rising to the equivalent of nearly 5,000,000 tons of coal per year.

The adoption of oil firing on an appreciable scale, and the longer-term development of nuclear generation, promise to change quite drastically the geographic pattern of fuel supplies. This may well result in significant changes in the siting of new power stations and the further development of the associated main transmission system.

275kV Grid

The grid system of main transmission lines owned and operated by the Central Authority comprised at March 31, 1955, 5582 route miles, of which 41 operated at 275kV, 5038 at 132kV, and the remainder at 66kV or lower voltages. The major grid development work put in hand during the year included 149 route miles of 275kV lines and 303 miles of 132kV lines.

Reinforcements of the grid system required to meet the growing load and to ensure reliability of supplies to consumers included arrangements for twenty-three more new points of supply to Area Board's networks, making a total of 120 in the seven years since vesting day. In respect of these 120 new supply points, it is estimated that there will be a total capital saving of approximately £11,600,000, compared with the costs which would have been incurred if requirements had been met by developing existing points of supply.

Technical Survey of Copper.—We have received a copy of the latest edition of the *Technical Survey* published twice a year by the Copper Development Association. This gives a comprehensive review of recent technical developments in the production, properties and applications of copper and its alloys, with an extensive bibliography. A copy will be supplied to any reader who makes personal application to the Copper Development Association at Kendals Hall, Radlett, Herts, with a request to be placed on the mailing list for future issues.

Heavy Duty Screens

A new range of heavy duty two-bearing, vibrating screens for the screening of dry or wet sand, gravel, crushed stone, ore, coal and for other industrial applications, has been introduced by Pegson, Ltd., Coalville, Leicestershire. These new "Vibro King" screens, as they are known, are made in single, double and triple deck models with screen sizes 8ft by 3ft, 10ft by 3ft, 10ft by 4ft, 12ft by 4ft, and 12ft by 5ft. They can be used for finishing screening of all sizes of aggregate and in certain applications for scalping service where the oversize to be handled is not too large or too heavy.

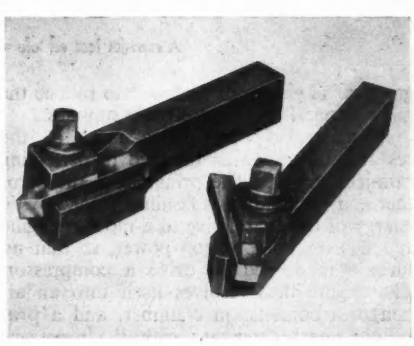
The screens have a horizontal main frame of heavy channels or "I"-beams, welded together and reinforced with gussets and angles. The vibrating frame of heavy steel side plates is reinforced longitudinally with angles which also serve to support the screen cloth trays. The entire vibrating mechanism, including the vibrating unit and screen cloth, floats on springs. The vibrating unit is mounted on two heavy duty roller bearings and is equipped with two enclosed and automatically adjusted counterweights which prevent the screen "jumping" at critical speeds and ensure smooth operation. Vibration, which is constant under light or heavy loads, is circular in motion and uniform on all parts of the screen cloth.

If required, the equipment can be supplied with steel screen trays or rubber-protected steel screen supports over which the screen cloth can be stretched. Alternatively, one deck can be furnished with a tray-mounted screen cloth and the other deck or decks with stretched wire cloth, according to requirements. When an equipment is used in washing plants for rinsing stone or gravel special spray pipes can be fitted, and these pipes are firmly attached to the screen frame so that they cannot interfere with or dampen efficient operation of the screen. Special nozzles are provided to deliver a uniform, predetermined amount of water over the whole screen surface, given a constant supply head. The cylindrical roller anti-friction bearings are protected against ingress of dirt and moisture by labyrinth and piston ring seals: provision is made for grease gun lubrication.

Tool Bit Holder

A new tool bit holder, introduced by James Neill and Co. (Sheffield), Ltd., Napier Street, Sheffield, for use with "Eclipse" bits, is illustrated below. These holders are made in three forms—straight, right hand, and left hand—and in two sizes for bits from $\frac{3}{16}$in to $\frac{1}{4}$in and $\frac{1}{16}$in to $\frac{3}{8}$in.

It will be seen that with this form of holder the bit is held rigidly in its groove by a downwards and sideways pressure imparted by the clamping block. This block has an angle recess along one side, which registers over the corner of the bit, and as it is tightened down an inclined face on the opposite side imparts a sideways wedging action to grip the tool firmly. The open groove in the holder is easy to clean and can quickly be swept free of swarf before inserting the bit.

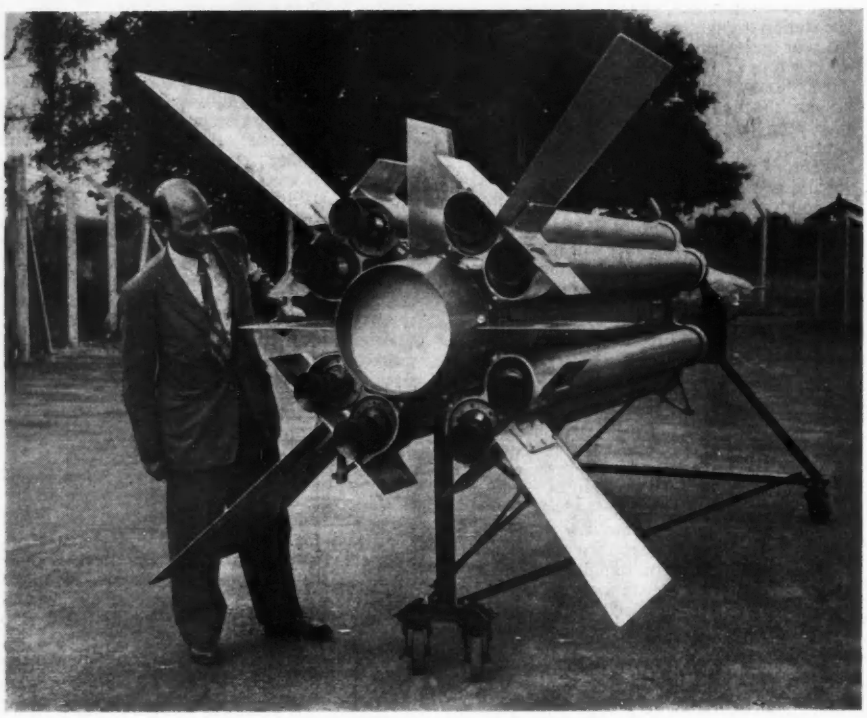


Tool bit holders in which the bit is locked rigidly between the angle of the groove and the angle of the clamp by a downwards and sideways pressure

Work of the National Gas Turbine Establishment

The N.G.T.E., Pyestock, Hants, recently held an Open Day on which its plant and work could be studied. While much of its activity is classified, some interesting recent work was displayed.

THE National Gas Turbine Establishment is occupied principally in research on gas turbines and their applications and on development testing of components where the facilities required are out of reach of the manufacturer. Because gas turbines are so frequently applied where the need is for great power, and because their output is normally the relatively small difference between turbine output and compressor intake powers, such work calls for powerful plant. Typical items are a steam turbine of about 15,000 h.p. for testing aero-engine compressors at less than sea level static power, and a 10,000 h.p. gas turbine generator intended to reduce the peak demand on the electricity supplies.



A ram-jet test vehicle with booster rockets attached

A particularly interesting facet of the research effort is that directed to perfecting ram-jet aircraft. The principle of the aero-thermodynamic duct is familiar : the kinetic energy of the air relative to a moving engine supplies the compression power, so that no turbine is needed to drive a compressor. The engine thus resolves itself into an air intake, a combustion chamber, and a propelling nozzle, together with the necessary fuel and control systems. It will be clear that such an engine cannot run except when flying, and in practice the nature of supersonic flow prescribes a range of speeds over which compression is efficient, depending upon the geometry of the intake. The test vehicle illustrated is provided with eight rockets to accelerate it from rest ; these rockets can break away from the ram jet when they are exhausted. The aircraft proper consists of a thick-walled tube ; a short aerofoil-section partition crossing the duct carries the air-turbine-driven fuel pumps and other equipment. Radio equipment is provided to allow the flight of the machine to be recorded.

Reliable lighting-up is obviously a vital requirement of such an engine, and that this is not easily achieved was demonstrated on the test bed. Two types of bed are employed for research on " athodyds," one in which air is fed directly into the duct to provide the specified conditions in the combustion chamber, and another in which the intake is placed in a high-speed air stream large enough to give effectively constant velocity over the air intake. To simulate conditions at high altitude, it may be necessary to enclose the unit and exhaust air from its surroundings. When flight speeds of the order of Mach 2 are required, models of a reduced size are used at the N.G.T.E. The magnitude of the air flows through these motors can be visualised from a figure of 5000 lb thrust obtained from an example resembling that illustrated when connected solidly to an air supply system.

Since the efficiency of compression is decided principally by the pattern of shock waves existing in the intake, the angle of attack is an important variable and models are arranged to yaw. The great acceleration of the initial rocket-powered flight is simulated by opening the air supply valves under the action of hydraulic rams.

Another research directed to reaction propulsion is concerned with the action of propelling nozzles over speed ranges transcending the sonic. Since the convergent-divergent nozzles needed for high propulsive efficiency at supersonic speeds are efficient only at one expansion ratio, a number of variable nozzles have been investigated on models. These range from a two-position nozzle through bullet types familiar on German jet engines to ducts made of numerous curved flexible strakes.

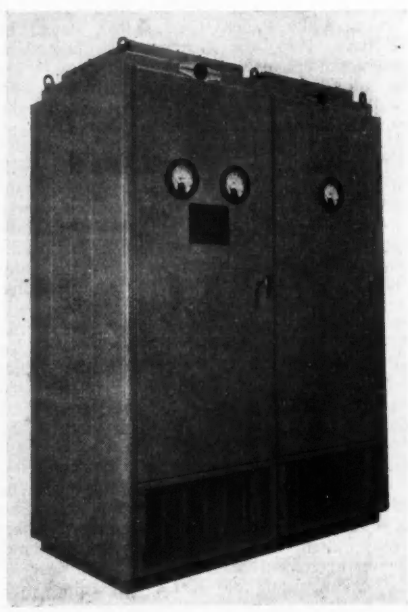
While aircraft, profiting from the conditions of low ambient temperature and high total pressure that they can seek, are the leading application of gas turbine engines, many of the problems besetting the industrial plant are being studied at the Establishment. The method of suppressing fouling and corrosion, of turbines in which residual grades of fuel oil are burnt, by allowing a slight measure of inefficiency in the combustion chamber, so that the lower melting point ash constituents remain in the unburnt carbon particles, is still considered hopeful, since, in running, should add only a few per cent to the fuel costs. A vortex type of chamber has been constructed in which it should be possible to establish close control of the burning of fuel droplets of uniform size.

Another economically attractive fuel for internal combustion turbines is coal, and for such applications experiments are being made with a through-flow cyclone separator to eliminate fly-ash from the turbine intake. A further interesting research connected with combustion demonstrated the delay in the spontaneous ignition of fuel gas/hot air mixtures.

Power Germanium Rectifier for Commercial Service in Great Britain

OUR illustration shows the first power germanium rectifier equipment to be taken into normal commercial service in this country.* It was made for Imperial Chemical Industries, Ltd., by The British Thomson-Houston Co. Ltd., Rugby, and was commissioned on August 31st last.

This rectifier is rated at 1000kW, 255V, 3920A, and it is designed to operate at continuous full load for long periods. It consists of two cubicles housing a series-parallel arrangement of air-cooled germanium rectifier cells connected to form a six-phase, full-wave bridge. An alternating current supply is taken from an existing delta/diametric-connected transformer which previously supplied a rotary converter.



The first germanium rectifier to go into normal commercial service in Great Britain. It has a rating of 1000kVA, 255V, 3920A

*See also THE ENGINEER, July 9, 1954 (page 53, and January 21, 1955 (pages 96-97).

Apprentice Training School at Crewe

LAST week a new training school for apprentices at Crewe locomotive works was officially opened by Sir Brian Robertson, the chairman of the British Transport Commission. This school was first authorised in 1951 and its foundation stone was laid two years later by Mr. R. A. Riddles. The need for such a school to alleviate the shortage of trade apprentices has long been felt at Crewe, where out of a total personnel of some 7000 a normal complement of 1000 apprentices is required, and this entails an intake of about 200 boys a year. For this reason the new school has been designed, equipped and staffed with a view to attracting suitable boys and provide for them a high standard of educational and vocational training prior to their entering the main works. In addition to providing for the requirements of the locomotive works the school undertakes the training of apprentices for other technical sections of British Railways, including the motive power, civil engineer's, signal engineer's and road motor departments.

Main workshop at Crewe apprentice training school

The school is designed for training some 200 locomotive works trade apprentices and 100 apprentices from other sections a year, and the scheme to be followed gives one year of practical and theoretical instruction to all apprentices upon engagement at the age of fifteen years. In this time it is aimed to introduce a boy to new conditions; give definite and systematic training in manual skill; ascertain a boy's natural aptitude and place him in a suitable trade; and widen his field of knowledge and general outlook. During his time at the school about 62 per cent of a boy's time will be spent in practical training, 22 per cent in direct workshop theoretical training, and the remainder on subjects designed to broaden his field of knowledge in more general matters.

The practical work of the school is divided into seven main sections—electrical; pattern-making and joinery; plate and sheet metal work, coppersmithing, electric and oxyacetylene welding; moulding, smithing and forging; turning and machining; fitting and assembly, and model-making. During his first three months in the school a boy will spend a period working in each practical section and then on the basis of the instructor's reports on his natural aptitude, and with his and his parents' agreement, the remainder of his training period is directed to one particular trade to which it is considered he will be best suited.

The school is situated on the site of the former carriage works, its site covering an area of some seven acres, immediately adjoining the Crewe works. It consists of a large single-storey workshop with an adjoining two-storey lecture room and administration block. A large gymnasium adjacent to the main buildings serves also as an assembly hall and cinema capable of seating some 400 people.

The main workshop building has reinforced concrete barrel vault roofing carried on reinforced concrete stanchions giving a clear span of 70ft. Cavity brick infilling panels between the stanchions include large areas of metal-framed windows, which, combined with the lights in the barrel vault roof, provide generous natural lighting over the whole floor area. The machines installed in the main area of the workshop, as can be seen from the illustration on this page, are well spaced to give both the boys and the instructors plenty of room and enable groups to form round particular machines during lectures. Waist-level walls separate the various sections of the shop and in separate smaller shops at one end are the smithy and moulding sections, the welding section and stores. The ground floor of the two-storey block is divided up into administrative offices, and on the first floor there are three lecture rooms, a science instruction room, a library, a drawing office, lecture room and store rooms.

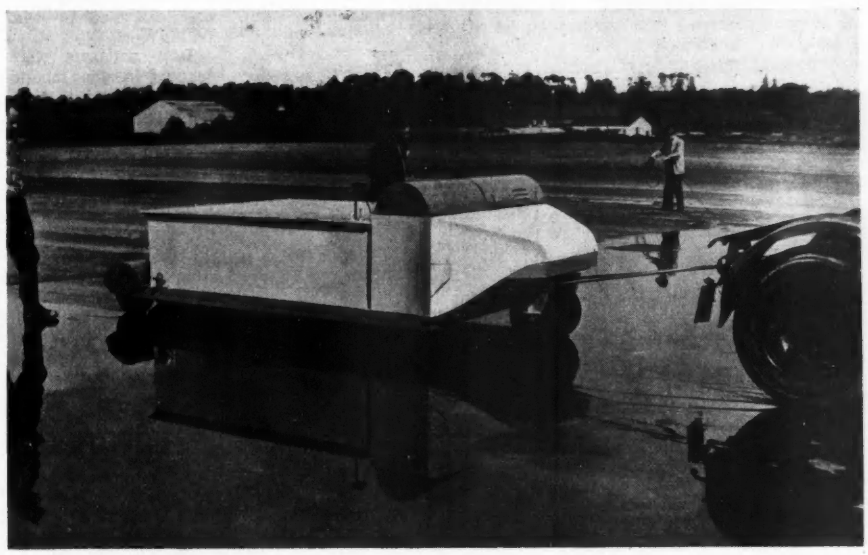
At the opening ceremony the speakers were introduced by Mr. J. W. Watkins, the general manager of the London Midland Region, who spoke of the traditions of the Crewe locomotive works and the many famous engineers who had received their training there. The new school, he said, was the most ambitious project of its kind yet undertaken and he paid tribute to the assistance and co-operation which had been received from the educational and other local authorities in carrying it out. To commemorate the occasion a bronze plaque was unveiled by Sir Brian Robertson, the chairman of the British Transport Commission, who promised the staff of the school the full backing of the Commission in the important work of training new craftsmen for the railways. He pointed out that the modernisation scheme put forward for British Railways would create the finest railway system in the world. This work would by no means bring about a redundancy in the ranks of skilled craftsmen but would, indeed, offer them far greater opportunities. In the realisation of the modernisation plans the new school would play an important part in maintaining and increasing the supply of craftsmen needed.

Aircraft Runway Drying Machine

POOLS of water on aircraft runways are a source of danger to jet aircraft landing at high speeds, and for this reason a machine for drying runways of aerodromes after rain storms has been developed and built by Cimex-Fraser Tuson, Ltd., of Orpington, Kent. The first of these machines has been acquired by Vickers-Armstrongs (Aircraft), Ltd., and it can be seen in the illustration below in operation before delivery to that firm's airfield at Weybridge.

The machine consists essentially of a fabricated channel steel frame mounted on four pneumatic wheels at the rear and three similar wheels on a castor head at the front. It is 13ft long overall by 6ft 4in wide and 3ft 10in high and is designed for towing by a tractor. Mounted on the frame is a totally enclosed fabricated steel tank of 400 gallons capacity, and there is a separate power compartment at the front.

In the power compartment a 3 h.p. Villiers engine drives a suction fan which is designed to create a vacuum in the tank. Depending from the rear of the tank is a squeegee, which is spring loaded into close contact with the surface of the runway, and runs across the full width of the machine. A slot above the rubbing surface along the front of the squeegee opens into a duct leading into the tank, so that as the machine



Runway drying machine in operation. With this machine water pushed up by a squeegee at the rear is sucked up into a 400-gallon capacity tank

moves along the water pushed up in front of the squeegee is sucked up into the tank. When the water in the tank reaches a pre-determined level it actuates a cut-out switch to stop the engine and prevents excess liquid being drawn into the fan compartment. Baffle plates are fitted in the tank to prevent water surge as the machine is drawn along.

When it is required to move the machine over dry patches on the runway or take it away after drying is completed a lever at the side is operated to raise the squeegee clear of the ground. The makers state that the machine is capable of removing water at a rate of 100 gallons a minute from a runway under normal conditions. When full to its capacity of 400 gallons the machine weighs 3 tons.

Fourteen-Head Spot-Welding Machine

THE accompanying illustrations show two views of a new fourteen-head spot-welding machine designed for the automatic welding of spacing strips across the faces of grids made up of steel bars on edge. This machine is made by Metropolitan-Vickers Electrical Company, Ltd., of Trafford Park, Manchester, 17.

Part of fourteen-head spot-welding machine and jig table arranged for welding spacing strips across grid

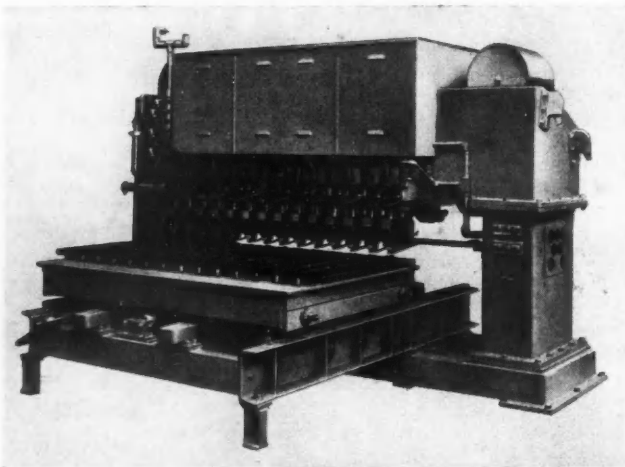
After a grid and its spacing strips have been loaded into the jig, depression of a push button initiates the welding cycle and the jig table is indexed through the machine. When the welding has been completed the table returns to its original position for unloading.

The kinked spacing strips are formed from $\frac{1}{16}$in by $\frac{1}{2}$in mild steel strips welded to the edge of $\frac{1}{2}$in black steel bars which vary in depth up to 2in. The strips are electro-forged into the bars to approximately half their thickness. The machine makes fourteen rows of welds per minute so that a grid of thirty longitudinal bars can be welded in 126 seconds, which provides an output, allowing for loading time, &c., of some seventeen grids per hour.

As can be seen, the machine consists of a welded steel arch frame. It has a clear span of 8ft, carrying fourteen electrode assemblies at 5in centres, each actuated by a 3$\frac{1}{2}$in bore, double-acting, 1000 lb air cylinder. The welding current for each pair of electrodes is provided by a 108kVA (nominal) air-cooled, single-phase transformer, and each electrode is water-cooled.

The jig table runs under the arch on rails and is driven by a $\frac{1}{2}$ h.p., three-phase, squirrel-cage induction motor through a worm reduction gear-box and Geneva mechanism.

A separate assembly contains the control gear, which includes seven Ignitron contactors and two thyratron timers and the associated relays and switches.



Fourteen-head spot-welding machine and jig table for welding spacing strips across grids made up of steel bars on edge

Conference on Structural Testing

ON Wednesday and Thursday of last week a conference was held at the Institution of Civil Engineers, at which twenty papers on various aspects of structural testing and investigation were discussed. The full title of the conference was "on the correlation between calculated and observed stresses and displacements in structures." A tendency apparent in recent structural engineering thought to emphasise the value of full-scale structural tests and of measurements made *in situ* on existing structures was particularly emphasised by the subject-matter of various papers at the congress. In most cases, such full-scale tests and measurements seem to have given, for practical purposes, a reasonable unification of much of the theoretical background of contemporary structural design.

The first session of the conference was entitled "philosophy and techniques of testing" and included three papers, all of which gave emphasis to tests in the field. Much of the experience gained by the Building Research Station in this class of work, in which the Station has been a pioneer, was summarised by Dr. F. G. Thomas, and some of the techniques and instruments used for measuring strains were discussed by Mr. W. H. Ward.

Steel structures were debated in the second conference session, when eight papers were presented. The work described in these papers included tests of the prestressed steel trusses recently erected at a factory at Harlow, and the site measurements of stresses in the steel frame of the new government offices in Whitehall Gardens. Full-scale tests were in evidence also in papers describing such tests on a Vierendeel girder, a welded plate girder floor system, a saw-tooth portal frame, and loading tests on highway bridges. Some of these tests were carried out to investigate design analyses based on plastic theory. This session also included some notes on the behaviour of Clifton suspension bridge, where some experimental measurements have recently been made, and a paper on the design of a raw sugar silo, abstracts from which are published on page 487 of this issue.

The telephone manager's office at Kilburn, which is now well known as a multi-storey design in prestressed concrete, was described in the third session of the conference, together with five other papers on the testing of concrete structures of various kinds. The way in which problems of statical indeterminateness were overcome in this design was described in our issue of July 17, 1953. As the structure was somewhat novel in conception, measuring apparatus was installed when it was built, and the results of measurements over a period of 2$\frac{1}{4}$ years are given in the paper. The main conclusions drawn from this investigation were that: (1) the magnitude of the prestress induced in the concrete beams and its distribution across the section was substantially that required in the design; there was, however, greater friction than had been expected between the precast beams of the partly cast floor panels and the main beams; (2) the sequence of construction was such that no undue stresses were imparted to the main prestressed concrete beams arising from the stressing of neighbouring beams, from supporting the shuttering during the casting of beams in the floor above, or from other constructional procedure; (3) the deformation of the beams in the loading tests was much less than had been expected in the design due to composite action between the beams and the floor panels; (4) the greatest loss of prestress in the steel due to creep and shrinkage of the concrete over a period of 2$\frac{1}{4}$ years was slightly less than the allowance assumed for design.

A number of tests on prestressed concrete and shell roof structures were described in the other papers of this session, including tests on the precast prestressed shell-roofed workshop block of Kingston-upon-Hull technical college, described in our issue of December 17, 1954. The behaviour of reinforced concrete structures was also commented upon in two papers, one of which described tests on reinforced concrete portal frames, and the other outlined tests on the floor systems of a building which had been in use for about ten years. The failing loads, in the latter example, exceeded those computed by both elastic and plastic theories, it was stated, but were in closer agreement with plastic theory.

Earth pressures and movements were the subjects of the final conference session. Three papers were presented, discussing settlement studies of various buildings, and comparisons between calculated and observed earth pressures and settlements of structures on clay. Messrs. Skempton and MacDonald noted in this paper that a number of comparisons between calculated and observed settlements of structures on clay had been published as individual case records, but few attempts had been made to carry out a general survey of the reliability of existing methods of calculation in that field. Sufficient information, however, was available to permit such a survey to be made, and in the paper settlement records of twenty structures were considered. They include nine cases for which the data were complete and eleven for which comparisons could be made only of the calculated and observed final settlements.

The results indicated that the method originated by Terzaghi for calculating the final long-term settlement of structures on clay was adequate for practical purposes. For calculating "immediate" settlements at the end of construction of the building elastic theory was used, and, in the cases where comparisons with observations could be made, reasonably good agreement was also found. The rate of settlement as calculated by the conventional method was found to be too slow, and better agreement with the actual rate of settlement was obtained by a method introduced recently and described in the paper. But there was room for further improvement in that aspect of the problem. The heave in deep or moderately deep excavations, and the corresponding settlement on replacing the overburden pressure by structural load, were matters on which there were not sufficient data to permit any conclusions to be drawn, and more work on that subject was also needed.

Design of a Raw Sugar Silo*

By E. T. MOSS, Ph.D., B.Sc. (Eng.)†

One of the more unusual structural problems discussed at the recent conference at the Institution of Civil Engineers concerned the design of a raw sugar silo. The abstract herewith outlines the design problem and its solution.

In order to present a complete account of the design of a raw sugar silo it is necessary to outline a number of the requirements for such a silo. In the first place it is useful to know the need—and hence the purpose—for storing raw sugar at a refinery. The day-to-day requirements are normally met by direct imports of raw sugar in order to obviate double handling, but the smooth flow of supplies is dependent upon a chain of factors which include the weather, the labour situation, and the arrival of ships from oversea. Raw sugar stores must act as a cushion to offset the otherwise adverse effect on the refinery caused by the breakdown of any of these factors.

The handling characteristics and the sucrose content of raw sugar are affected by the temperature and humidity of the air close to the sugar and by its moisture content. A refinery handling many types of raw sugar from various oversea markets must be able to store these sugars safely without deterioration due to micro-organisms and without undue caking of the sugar which can make it impossible to handle. It can be seen, therefore, that the design of a raw sugar silo must, as far as possible, take these factors into account in order to be successful.

There are many silos in existence which are used for the storage of raw sugar and of other materials such as phosphate fertilizer. Different materials of construction and various shapes and designs are used in these silos; many of which were considered when the present silo was to be constructed. All silos can be divided into two main categories, namely, those having the walls subjected to internal pressure due to the contents, and those using the walls merely to support the roof and give protection against the weather. These two types of silo are generally referred to as "pressure storage" and "non-pressure storage."‡ The choice of the former type for the silo erected at the London refinery at Plaistow Wharf was made for two reasons: (1) the high cost of land favours the maximum use of height, which implies pressure storage using a small ground area per unit weight of sugar; (2) a pressure silo lends itself to much better control of temperature and humidity conditions in the silo.

Steel and reinforced concrete are the main materials for the construction of a pressure silo. Designs were drawn up for a silo in each of these constructional materials. The steel one was based on previous designs used successfully in Sweden, whilst the reinforced concrete was of parabolic shape and similar to silos already in use in this country for fertiliser storage. It was agreed for a number of reasons, including that of cost, to proceed with the steel cylindrical silo and it is this which forms the subject of the present paper. The illustration herewith shows the general features of this silo.

Foundations

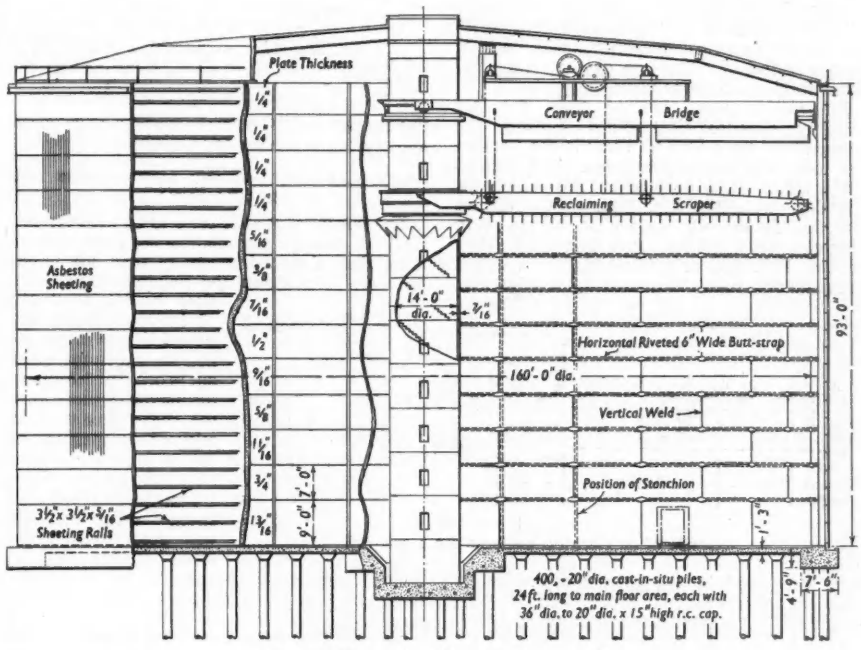
The site of the silo was investigated by a borehole which showed that the following strata were present. The top layer of peaty clay to a depth of 22ft was followed by Thames River gravel to a depth of 40ft resting on 16ft of London Clay. Below this a 6ft layer of flint pebbles (Blackheath beds) were encountered resting on the Woolwich and Reading beds of sand and clay to a depth of 119ft, where the borehole was terminated.

The London Clay will carry loads up to 4 tons per square foot, and therefore it is only necessary in the case of very heavy loads to carry the foundations below this stratum. A loading of approximately 2 tons per square foot would result from a silo full of sugar.

It was decided to drive piles to a depth of about 25ft so that the load would be taken by the gravel and by the lower strata. Due to the acidic nature of the ground, according to its history, special piles having the outer casing in aluminous cement were used.

It was realised that the loading on the foundations would not be uniform since the central tower and the shell would transmit a considerable portion of the sugar load by friction. In order to accommodate this loading the floor of the silo, which was made of reinforced concrete 15in thick over the major portion, was thickened to over 4ft at the periphery, under the shell, and at the centre under the tower. This made, in effect, two continuous rings for the additional loading in these areas.

In order to obtain full information on the loading and settlement of the silo a total of twenty-eight points—sixteen around the base of the shell and twelve over the floor—were made at which the precise level could be checked with reference to a fixed level outside. There was a settlement of slightly more than 1in with 38,000 tons in the silo. After emptying there was a recovery, on average, of nearly ½in. The settlement inside the silo area was appreciably greater than that recorded at the perimeter. This indicates that the ring beam under the shell was quite adequate for the additional loading in this region.



Part elevation, part section of raw sugar silo

Roof Design

As will be indicated in the section dealing with thermal insulation, the main requirement for the roof of the silo was that it should have maximum insulation compatible with cost. This led to the use of precast cellular concrete slabs, 3½in thick, resting on steel angle purlins. The whole roof was covered with bitumenised felt and a coating of feldspar to improve the absorption coefficient and thereby lessen the effect of the sun's radiation.

Shell Fabrication

The silo shell consists of thirteen strakes each made up of sixteen plates enclosed in a framework of 18in by 6in stanchions. The plates in the bottom strake are $\frac{13}{16}$in thick and the thickness of each plate above this is decreased by $\frac{1}{16}$in until the minimum of ¼in thick is reached at the tenth strake.

The vertical seams of strakes one to eleven are positioned to one side of alternate stanchions and were welded from both sides of the plate. The vertical seams of the upper two strakes, twelve and thirteen, coincide with the centre-line of alternate stanchions and are welded from the inside using the stanchion as a backing plate.

The lower nine horizontal seams were closed by single riveted straps on the outside of the shell. The upper three remaining seams were welded from both sides of the plate.

These remarks on the actual method of fabricating the shell are made because they differ from the original intention which was to have a fully welded structure. This alteration in the design was made at a late stage when news of recent failures in similar structures which had been welded was obtained. By employing riveted straps for the horizontal joints any failure in the shell, such as might be caused by a brittle fracture, should be restricted to one strake. In addition, a rigid system of weld inspection was instituted in order to minimise the possibility of a brittle fracture commencing from a fault in the weld.

Both ultrasonic testing and spot X-ray tests were used for the welding. It was found that the standard of welding, which had been set with reference to some test welds made before commencing the main structure, could not be attained. Inspection revealed lack of fusion, lack of penetration, gross slag inclusions and undercutting. Considerable lengths of weld had to be chipped out and rewelded, in some cases as many as three or four times. Progress was retarded so much by these faults that a relaxation of standard had to be made during the erection.

The final position with regard to testing the welds was that the four lower strakes only were completely examined by the ultrasonic method together with local X-ray tests. The remaining strakes were subjected to spot X-ray examination at the discretion of the surveyor. Complete records have been kept so that in the unlikely event of a failure in the future information will be available to assist an investigation.

Thermal Insulation

Reference was made to the importance of temperature variation on the properties of stored sugar. It is not proposed to elaborate this point other than to say that a number of workers in various countries have obtained data which indicate the optimum conditions and the maximum changes in temperature that can be tolerated by raw sugars.

When a number of schemes were drawn up for the walls and roof of the proposed London silo it was possible to compare them on a thermal basis by evaluating the overall heat transfer coefficients. However, this method gave only relative insulation properties and could not give

* Abstracts from a paper presented, at the Institution of Civil Engineers' conference on the correlation of calculations and observed stresses and displacements in structures. September 21st.

† Chemical engineer, Research Laboratory, Tate and Lyle, Ltd., Keston, Kent.

‡ The references are given in the original paper.

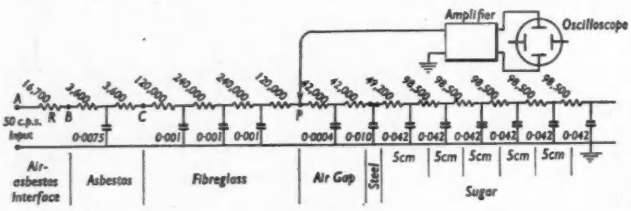
any definite information regarding temperature variations inside the silo. The only reference which was available for these coefficients was that obtained from the raw sugar silos in use in Sweden. These silos are only used for beet sugar which has different characteristics from cane raw sugar; in addition these silos are lined with wood which probably has a beneficial effect regarding temperature and humidity changes. In order to obtain some more definite information use was made of an electrical analogue.

This ingenious method for the determination of unsteady heat flow through any system was devised by Beuken in 1937 and later developed by Paschkis and Baker. The basis of the method is the ability to build an electrical system of condensers and resistances that is analogous to the thermal system—i.e. the silo roof or wall—which is being investigated. Thus in the analogy we have the following quantities :—

Temperature	Voltage
Thermal resistance	Electrical resistance
Thermal capacity	Electrical capacity
Heat	Electric charge
Flow of heat	Current

By using 50 c/s alternating current, any period of time such as one day or one year in the silo system can be represented by one-fiftieth second in the electrical system. It can be shown that little error is introduced by regarding the variations in atmospheric temperature outside the silo, over a period of either one day or one year, as conforming to a sine wave.

Information was obtained from the Air Ministry meteorological office showing the temperature drops (day to night) in the London area over a period of five years. The average daily temperature drop over this time was 15½ deg. with 37½ deg. Fah. as the highest recorded figure. On only eight occasions in five years was the temperature drop greater than 35 deg. Fah. and only fifty-eight times was it above 30 deg. Fah. This latter figure of 30 deg. Fah. was used in the calculations with the analogue experiments. A figure of 25 deg. Fah. was used for the annual temperature drop from July to January.



Example of an electrical analogue for a silo wall

The diagram indicates the way in which the various resistances were linked together to represent, in this case, an example of a silo wall. The amplifier of the cathode-ray oscillograph was connected between earth and a probe, *P*, which could be applied at any point *A*, *B*, *C*, &c. With the probe at point *A*, the amplifier was set by adjusting the input voltage so that a wave-form was seen on the oscillograph with an amplitude which could be measured. The probe was then applied to any point in the system and the amplitude again measured, the ratio of this to the amplitude at point *A* being determined. This ratio was termed the "insulation factor" and was equal to the ratio of the temperature variation at the point to that in the air outside the silo. Thus it was possible to determine the temperature fluctuation at any point in the silo due to an assumed daily temperature variation of 30 deg. Fah. in the outside air.

Quite apart from the temperature variations caused by the outside air temperature there is also the heating effect brought about by direct radiation from the sun. To represent this the electrical analogue was modified by connecting the point *A* to earth and feeding current having the correct magnitude and wave form into the circuit at *B*. The resistance *R* then represents the loss of heat from the silo surface to the outside air by re-radiation, conduction and convection.

Since the temperature changes in the silo due to outside air changes and solar radiation may both be a maximum together in mid-summer it is seen that the two results must be added to obtain the maximum possible change in temperature within the silo. It is not intended to present full results of the many cases which were considered by the analogue method, but the table gives figures for the accepted design in contrast to a design with no insulation. The very considerable advantage of the additional insulation for the cavity wall of the silo can be seen. The relatively poor insulation of the roof is also obvious. Although the cellular concrete roof of the accepted design is more than twice as effective as the alternative design it is still likely that condensation will occur on the underside of the roof. The installation of a fan-ventilating system was made in the light of this investigation ;

TABLE—*Temperature Drop Inside Silo Wall With Worst Possible Climatic Conditions*

Silo design	Temperature drop (deg. Fah.)
Accepted design (with 3in fibreglass)	2¼
With no additional insulation	21½

Temperature Drop Through Roof of Silo With Worst Possible Climatic Conditions

Roof design	Temperature drop (deg. Fah.)	
	Under roof	Top surface of sugar
Cellular concrete	20½	12
Steel and roofing felt	53	31

this enables the air above the sugar to be changed and overcomes condensation troubles.

Stress Calculations and Observations for the Silo Shell

The thickness of steel plate to be used for the shell was of some considerable economic importance since the total weight of steel was large. In order to calculate the required strength of plate the lateral thrust of the sugar in the silo is needed. An investigation was therefore carried out in order to determine this factor by measuring the shear strength and relevant properties of raw sugar. These tests were carried out in a "controlled rate of strain" shear box. It was possible from the results of these tests to assume the lateral pressure, p, of the sugar (density d) at any depth, h, in the silo to be given by $p = 0{\cdot}4d \,.\, h$.

This was the basis of the calculations for plate thickness of the silo shell. It was realised that this was only an approximation since no allowance was made in this equation for the reduction in pressure due to vertical shear forces between the shell and the sugar. These shear forces were unknown, but were important when designing the foundations because they would permit calculation of the sugar loading transmitted via the shell.

In view of the scarcity of information, and with a quest for knowledge so that future design calculations could be made more easily, it was decided to take measurements of strain in the silo shell when the silo was filled with sugar.

[The remainder of this paper was devoted to a description of these measurements and the results obtained.]

Gas From Oil.—We are informed that an agreement has been signed between the British Petroleum Company, Ltd., and the South Eastern Gas Board for the production of town gas from oil in a plant to be erected on a site, leased by the board from the British Petroleum Company, Ltd., which has an area sufficient for the construction of plant having a daily capacity of 80 million cubic feet. In the first stage 15-20 million cubic feet of gas will be produced per day from about 60,000-70,000 tons of oil per year and resulting in an annual saving of 300,000 tons of coal. Mains will be laid from the Isle of Grain to Strood in Kent, to feed the gas into a trunk main system.

Rise of Drag at Speeds near Sonic*

The work of Richard T. Whitcomb of the National Advisory Committee for Aeronautics on the drag of wing-body combinations, resulting in what is frequently referred to as the "area rule," has already contributed to supersonic flight by the Convair "Delta" all-weather interceptor and the Grumman "Tiger" carrier-borne interceptor. In application, the rule states that, for low drag at transonic speeds, the total cross-sectional area at any axial position on an aircraft should be the same as that of a body of revolution possessing a low drag rise at sonic speeds.

The early work to establish the theory was done in the 8ft transonic wind tunnel at the Langley Aeronautical Laboratory. The models used most extensively in the tests comprised a pointed cylindrical body, reaching a uniform diameter of 1·875in, 22½in from the nose, with a low aspect ratio wing, 4 per cent thick, tapered on leading and trailing edges, but with the quarter-chord line unswept. A wing with the planform reversed, so that the three-quarter-chord line was unswept, is referred to as a delta. A 45 deg. swept wing of aspect ratio 4 was tried, both on the cylindrical body and a finer fuselage with a curved after-body.

Schlieren photographs suggested, and the measured drags shown in Fig. 1 confirmed,

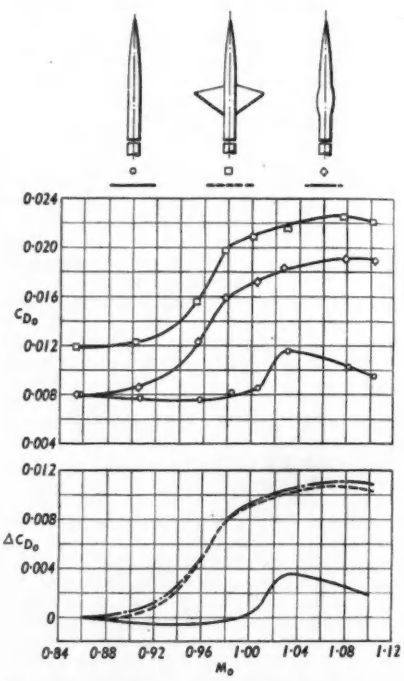


Fig. 1—Comparisons of the drag rise for the unswept-wing and cylindrical-body combination with that for the comparable body of revolution and the cylindrical body alone

that the behaviour of the wing-body combination is very close to that of a solid of revolution having at every section normal to the airstream the same area. It is seen that the absolute drag coefficients of the wing-body combination and the comparable body of revolution differ, primarily because of differences in skin friction, but the increments of drag coefficient over that at $M = 0{\cdot}85$ are the same within the probable accuracy of the data. All drag coefficients are based on a gross wing area of 1 square foot, the model illustrated having had a span of 2ft and a chord at the longitudinal axis of 12in. For the delta wing the same correspondence existed, but with the swept wing and cylindrical body there were deviations attributed to the smaller taper and the greater thickness of 6 per cent. The swept wing/curved body combination has a great deal higher drag rise, but, significantly, the increase

* Abstract of N.A.C.A. Research Memorandum L52H108 "A Study of Zero-Lift Drag Rise Characteristics of Wing-Body Combinations Near the Speed of Sound," as printed by *Aviation Week*.

was approximately reproduced by the comparable body of revolution.

Thence it was concluded that, near the speed of sound, the zero-lift drag rise of a thin low-aspect-ratio wing-body combination is primarily dependent on the axial distribution of cross-sectional areas.

This conclusion has been applied to a selection of published drag results and shows promise of predicting the effects of various design alterations. It has also been used to interpret variations of drag rise characteristics, showing that a given rate of decrease of area generally results in a greater drag rise than a similar increase.

However, the logical culmination of the theory

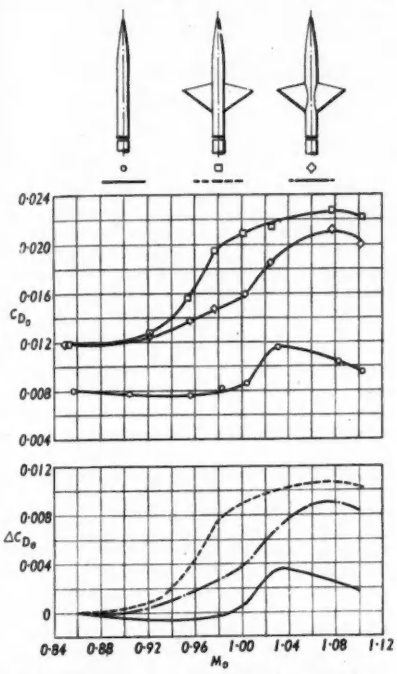


Fig. 2—The effect on trans-sonic drag obtained by indenting the body of a wing-body combination

is to modify the actual body to give a comparable solid of revolution with the shape of the original body alone. The effect of this with the unswept wing is shown in Fig. 2. Here the increments of drag were reduced by approximately 60 per cent near the speed of sound. With the swept wing, drag rise was eliminated up to $M=1{\cdot}04$ and this result is considered to be within reach of unswept and delta configurations if allowance were made for the deflection of flow by the boundary layer. Similar drag reductions have also been obtained at lift coefficients up to $C_L=0{\cdot}3$.

Thus, the report established that indenting a body, so that the axial distribution of cross-sectional area of the wing-body combination was that of a low drag rise body, greatly reduced or eliminated the drag rise increments associated with wings near the speed of sound.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

PROJECTION WELDING OF LOW CARBON STEEL SHEET AND STRIP

No. 2630 : 1955. Price 2s. 6d. This standard is based on two reports of the B.W.R.A. Committee and due note has been taken of their recommendations. This is one of the process standards in the comprehensive series for the resistance welding of steel. It specifies the general requirements for the projection welding of low carbon steel sheet and strip under normal conditions of manufacture and service. The design of dies, electrodes and inserts is covered, in addition to methods of testing and welding procedure. One of the appendices includes a table giving recommendations for projections for welding two sheets of equal thickness, based on the B.W.R.A. memorandum T.30. Recommendations for the types of welding machines to be used are also given.

Continental Engineering News

West German Oil Industry

As a result of large investments made in 1954, the West German oil processing industry has increased its capacity to over 12·6 million tons annually. Of this, 35 per cent is produced at Hamburg, another main centre being the Ruhr district, where 3·5 million tons a year are refined at five big refineries at Gelsenkirchen, Mülheim, Oberhausen and Bottrop. Owing to the relatively high coal prices, the production of oil from coal has at present receded into the background. Last year, the oil industry employed about 14,000 men on production, and 20,000 on processing. Deutsche Shell A.G. is reported to be planning to double the output of its refineries at Hamburg to an annual figure of 2·6 million tons, and to have earmarked D.M.200 million for this purpose.

While the relatively scarce oil deposits in Germany will never permit the Federal Republic to be completely independent of oil imports, every effort is being made to increase home production. By expanding the refining capacity to its present level, Germany requires to import only some 10 per cent of its total oil in the form of finished products. Prospecting continues, with 136 test bores being sunk in 1954, of which twelve struck oil. The total number of oilfields is now fifty-nine, but output is meagre compared with other countries, 30 to 40 tons a day from depths down to 6000ft being considered fairly satisfactory, compared with other parts of the world, where 1000 tons per field, from depths of 1200ft to 1500ft, is regarded as normal. It is hoped to produce this year over 3,000,000 tons, compared to the total requirements of 10,000,000 tons (against 8·6 million tons consumed in 1954). In 1954, 2671 wells were in operation, which averaged 2·4 to 2·7 tons a day each. The richest fields are those at Rühlenmoor and Georgsdorf, which each have an annual output of 200,000 tons. It is estimated that German reserves total 65,000,000 tons, sufficient for about twenty-five years.

Steep Gradient Endless Conveyor

The endless conveyor installation shown in the accompanying illustration (Fig. 1) was installed a few months ago in an open-cast brown coal mine of the Rhineland. Designed and built by Lauchhammer Maschinenbau und Stahlbau G.m.b.H., Düsseldorf-Benrath, the conveyor has a capacity of 1440 cubic metres per hour at a speed of 3·8m per second. Difference in level between loading and discharge points is 36m, and the inclination of the belt is 36 deg., which is the slope of the ground. It has, however, been shown by tests that the design will operate successfully on gradients up to 60 deg. The principle, as may be seen from Fig. 2, consists in placing the pieces of rock, coal or other material, on an ordinary conveyor belt and loading them with a flexible and easily-stretched chain mat to prevent slipping. This mat is also in the form of an endless belt and is returned by a separately driven second belt conveyor placed above the main conveyor. The weight of this mat depends upon the nature of the material to be conveyed and upon the gradient. It has been found that incomplete loading and starting and stopping have no effect upon the ability of the chain belt to hold the charge without slip.

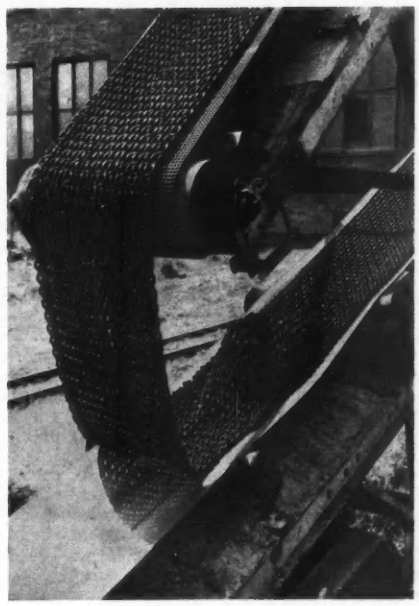


Fig. 2—The conveyor load is prevented from slipping by an endless chain mat laid over it

In the installation (Fig. 1) the steep-slope conveyor is charged by means of a short loading belt which helps to accelerate the material. The main conveyor at this point is inclined at 10 deg. to the horizontal and from there bends upwards in a curve to attain the full 36 deg. gradient. The curvature of this part of the belt can be calculated from the known belt tension and load, including the chain. The rollers must be positioned so that contact is maintained under all circumstances. Allowance has been made for the possibility of subsidence by constructing the frame in separately adjustable sections. Removal at the discharge point is by means of large railway trucks running on two tracks. It is thought that this principle will find an important application in rotary excavators which would be able to work to considerable depths below the horizontal.

Fig. 1—Steep-slope conveyor operating in open-cast brown coal mine

Industrial and Labour Notes

Overseas Trade

The Board of Trade's final figures concerning the United Kingdom's overseas trade in August show the value of exports as £264,200,000. This, it is stated, indicates a marked recovery from the effects of the railway and dock strikes which depressed the figures for June and July so severely. When June, July and August are taken together, however, the monthly average value of exports was £214,600,000, a figure which was well below the level reached in the earlier part of the year. But in the first eight months of this year, exports were 5 per cent higher than in the corresponding period of 1954. The Board of Trade says it is likely that further instalments of catching up on delayed shipments will be reflected in the trade figures for two or three months to come. Chemicals, machinery and manufactures of metal were prominent in the high export figure for August. Re-exports, which amounted to £10,000,000 in August, were the highest since March, shipments of copper to the U.S.A. accounting for a large part of the increase. Imports in August were valued at £342,300,000. In the first eight months of the year the value of imports was 16 per cent higher than in the comparable period of 1954, the import price index having risen by 4 per cent between the two periods. The increase in the volume of imports was approximately one-eighth.

The Board of Trade explains that among the widespread increases in the United Kingdom's exports in August several particular classes of goods stand out. In some instances, of course, notably iron and steel, these were goods which had been especially severely affected by the strikes. Shipments of engineering products last month amounted to £100 million, and contributed nearly £15,000,000 to the total rise in exports between July and August. Machinery, other than electric, rose by over £7,000,000 to nearly £43,000,000, and there was an even sharper proportionate rise of £6,000,000 to £19,000,000, for electrical machinery. August exports of road vehicles and aircraft, valued at £28,000,000, showed relatively little change from July or from the monthly rate in the first half of the year ; exports of aeroplanes and parts were £900,000 less and of cars £1,100,000 less than in July, but exports of commercial vehicles and of cycles were each £800,000 higher. Exports of metals and metal manufactures amounted to nearly £37,000,000 in August, an increase of £8,000,000 over July. In this group, iron and steel exports rose by nearly £3,500,000 in August to £14,250,000, and were slightly above the level for the first five months of the year. In other classes, the Board of Trade says, the August exports of coal and petroleum were both a little higher than those for July, but they were below the rate for the first half of the year.

Industrial Production

The Treasury has stated in *Bulletin for Industry* that in the first seven months of this year industrial production in Great Britain was 6 per cent higher than in the comparable period of last year. This was much the same rate of increase as in the second half of last year. The index of industrial production (1948=100) is estimated at 135 or 136 for all industries, which suggests, the *Bulletin* says, that production was rising again at much the same rate as before the transport strikes. There was a further small rise in civil employment during July, which brought the total to 290,000 more than a year earlier. The number of vacancies unfilled increased, and at the end of July it was 473,000, or more than two and a half times the number of unemployed.

The *Bulletin* goes on to record that coal output in the first thirty-six weeks of this year was 3,300,000 tons lower than in the corresponding period of last year. The warm weather of recent weeks, it is stated, has led to a fall in coal consumption ; up to the middle of July it was more than 1,250,000 tons above last year, but in the next five weeks it was nearly 250,000 tons lower. Coal exports in the first thirty-five weeks of the year, at 7,500,000 tons, were 1,700,000 tons lower than a year earlier, and imports were 8,000,000 tons, compared with 1,000,000 tons in the corresponding period of 1954. There has been some rebuilding of coal stocks from the low figure to which they fell in mid-April, when they were 2,600,000 tons down on a year earlier. Steel output in ingot tons rose sharply in August, and was 6 per cent up on a year earlier. The excess of demand for steel over production from home sources is being met by imports of crude and finished steel. These, the *Bulletin* notes, are likely to total 1,800,000 ingot tons this year, equal to about 9 per cent of an annual crude output of 19,600,000 ingot tons.

The *Bulletin* adds that the rise in the metal-using industries taken together has been much faster than the average for all industries ; in the first four months the gain over a year earlier was 11 per cent. It was particularly marked in metal consumer goods and motor-cars, both heavy users of sheet steel. In both cases, it is explained, the extra production was largely for the home market. The increase in output of metal consumer goods in the first quarter of this year was 21 per cent above a year earlier, and the provisional figures indicate that this rate of rise continued in the second quarter.

Steel Plant Extensions

Two announcements about further extensions to iron and steel plants have been made by The United Steel Companies, Ltd. The first of these concerns the Scunthorpe works of the Appleby-Frodingham Steel Company, where a new turbo-blower, costing over £750,000, an additional open-hearth furnace, costing £800,000, and an ingot stocking, handling and loading gantry, complete with a 7-ton electric overhead travelling crane, costing £100,000, are to be installed. The turbo-blower and the open-hearth furnace are expected to be ready for operation early in 1957. The furnace, which will be a 300–350-ton tilting furnace, will be the third unit in the Frodingham melting shop, and will produce about 120,000 tons of steel annually. To accommodate the furnace, an extension is being made to the melting shop building, and provision is being made for the installation of a fourth furnace at some future date. The extension will be 312ft long in the stockyard bay and 273ft long in the furnace and casting bays.

The other announcement is about a rolling mill modernisation scheme at the works, in Cumberland, of the Workington Iron and Steel Company. The scheme falls into two major sections, the replacement of two old steam engines which drive the roughing and finishing stands of the rail mill by two electric drives, and the reconstruction of another smaller mill which is mainly engaged in rolling the bars from which fish plates and bearing plates are produced. At the same time, the rail mill is being moved 40ft from its present position, with the dual objective of obtaining a layout designed for higher production and to enable the reconstruction to proceed without seriously interrupting the present output. The smaller mill, known as the fish plate mill, is being moved about 80ft from its present position, which will allow almost the whole of the installation to proceed without interfering with the working of the present mill. Reconstruction of the fish plate mill, which is expected to be completed by the end of this year, will enable output to be stepped up from 7800 to 11,400 tons a year. The cost of this project is put at over £1,000,000.

Costs and Prices

In the Treasury's *Bulletin for Industry*, mentioned in a preceding note, reference is made to costs and prices in British industry. It is pointed out that wages this year have been rising faster than before ; in the first seven months about 10,700,000 wage earners received increases, compared with 10,100,000 in the whole of 1954 and 9,000,000 in 1953. By the end of July, increases in wage rates granted since the beginning of the year had added £4,200,000 to the nation's weekly wage bill. These increases alone, the *Bulletin* comments, have added about £218 million to the yearly wages bill. At the end of last month, wage claims were outstanding in a number of industries, including agriculture, engineering and shipbuilding, and road passenger transport, and in the coal-mining industry a claim has been made for a reduction in working hours.

The *Bulletin* says that no figures are available on the recent trend of profits ; reports published by industrial companies in the first seven months of this year relate to accounting years ended between the summer of last year and the spring of this. The reports show, however, that ordinary dividends declared this year have been rising almost as fast as before. Net dividends declared by 1886 industrial companies in the first seven months of this year totalled £151 million, an increase of 21 per cent over a year earlier, compared with an increase of 22 per cent a year before that. Output also has been rising this year about as fast as in the second half of last year, but not quite so fast as in the first half, and home costs per unit of output have gone on rising.

Over the first seven months of this year, the *Bulletin* continues, import prices were 4 per cent higher than a year earlier, but in recent months they have tended to fall. In the same period, the index of retail prices (June, 1947=100) averaged 147, or 4·1 per cent higher than a year earlier, and the wholesale price index for manufactured products, other than fuel, food and tobacco (June, 1949=100) averaged 128·2, an increase of 2·5 per cent on a year earlier, compared with a fall of 0·4 per cent in the corresponding period of last year.

On the strength of " the imperfect and incomplete statistics " available, the Treasury says, it would appear that incomes have continued this year to rise faster than output. Home costs per unit have, therefore, again increased.

Wage Claims

The matter of wage claims was referred to last week by Sir Harry Railing, in his chairman's address at the annual meeting of the General Electric Company, Ltd. He said that if incomes continued to grow disproportionately to the output of goods and services, a reduction in real wages was bound to result. While the facts were recognised by all responsible leaders in every position and in every party, they were, unfortunately, still not realised by large sections of the community. Unwillingness to face economic realities, or lack of courage to do so, Sir Harry commented, were responsible for such claims as, for example, the present one in the engineering industries.

The engineering trade unions, Sir Harry continued, had recently submitted a claim for " a substantial increase," and it was understood that they were thinking in terms of a 10 per cent rise. In addition, there were resolutions recently adopted by the unions calling for a reduction in the working week from forty-four to forty hours without loss of pay, and for an additional week of holiday with pay. The granting of these and other demands which had been tabled, even without the inevitable repercussions on services, Sir Harry asserted, would add some 8 per cent to 10 per cent to the cost of the industry's products.

It had to be stated, Sir Harry said, that the annual raising of new demands of this character, both in the engineering and other industries, almost immediately after last year's demands had been settled, contributed more than any other factor to the handicapping of our export trade. They made it impossible to quote firm prices for long-term contracts. The damage, Sir Harry added, was especially great in the electrical and capital goods industry, on account of its high labour content.

The American Scene

BY OUR AMERICAN EDITOR

Floods in the North-Eastern United States

Over a month has passed since the tumultuous floods in the wake of hurricane "Diane" devastated large sectors of the north-eastern United States. Since then the enormity of the flood's damage has been revealed in human, economic and civic terms. The overall damage was staggering. In the six badly hurt states—Connecticut, New Jersey, New York, Massachusetts, Pennsylvania and Rhode Island—the death toll stood at 191 and many more were still missing. Total property damage was estimated at 1700 million dollars. More than 20,000 homes were destroyed or damaged ; 40,000 people were homeless, and 75,000 were unemployed. Equally staggering was the required relief. Within hours after the onset of the deluge the Red Cross set aside 2,000,000 dollars for preliminary aid and had sent 300 of its disaster specialists to help the 10,000 families needing assistance. The states concerned, to the limit of their ability, also took action to meet some of the cost. But the scope of the overall problem was far beyond the powers of private and state relief ; the Federal Government has had to allocate special funds to the U.S. Army Corps of Engineers to provide the states with emergency grants to restore public facilities. The tremendous devastation raised an old problem throughout the north-east and in Washington : what to do to minimise flood damage in the area in the future ? Ever since 1936, when Congress passed the Federal Flood Control Act, the U.S. Army Corps of Engineers has had on hand a comprehensive flood control plan calling for the construction of adequate dams, dykes, underground conduits and pumping stations in all major river basins in the region. But succeeding Congresses have appropriated only about 300 million dollars—enough to permit the Corps to complete only half of the plan. Thus, construction has centred on the main rivers in the area—the Connecticut, the Susquehana—at the expense of the tributaries. Areas where such construction has been completed escaped serious damage during this latest flood. But neglected areas, especially those of the tributaries, were badly hit.

Strong demands for speeding long-range flood-prevention measures were being pressed last month as the north-east of the United States counted its losses—in lives, property and employment opportunities—from its worst natural disaster of recent years. The value of flood-control measures was underlined by the distribution of storm and flood damage. In areas where control works were built after the disastrous storm and flood of 1935, new damage was held to a minimum. Most of the destruction occurred on streams where no control works had been built in recent years. There was substantial agreement among Federal and state officials that a good deal of the latest damage in New York, New Jersey and Pennsylvania could have been avoided if the "Incodel" plan had gone through. This plan is named after the Interstate Commission on the Delaware River basin. It called for the construction of a series of dams and reservoirs on the Delaware River and various tributaries to meet the water supply needs of communities in the three states. The project was abandoned some years ago when Pennsylvania objected to certain aspects of the plan. There also was substantial agreement that the damage in the three states would have been even worse except for the water supply reservoirs that the City of New York has built in recent years to tap the headwaters of the Delaware. Other New York City water supply schemes were credited with preventing serious loss of life and destruction of property in various sections of the Catskill Mountains. Most of the flood-control works in the north-east are the result of the Federal Flood Control Act of 1936. This established the general policy that the Federal Government would pay for all the costs of planning and constructing flood-control projects if the states and local governments provided necessary lands and easements and would maintain the works after completion. The U.S. Army Corps of Engineers was assigned to plan and build the necessary flood-control works. The money for the projects has been appropriated by Congress from time to time. All of the projects were undertaken with the co-operation of state and local governments.

In general, the control works consist of check dams and storage reservoirs that hold back the flow of rivers and their tributaries during flood stages and allow it to run out when the danger of flood is past ; dykes and levees that prevent rivers from overflowing their banks during flood stages ; the clearing and deepening of channels to allow rivers to carry more water without overflowing and the removal of obstructions from channels to prevent rivers from becoming temporarily dammed during high water periods. About 86,000,000 dollars has been spent in New York alone under the 1936 Federal Act. Of this about 80,000,000 dollars was supplied by the Federal Government and 6,000,000 dollars by the state and local governments. Corresponding expenditures have been made in the other north-eastern states. In Pennsylvania the outlays have amounted to more than 162,000,000 dollars and another 28,000,000 dollars worth of control work are now under construction. In New England the expenditures have amounted to 60,000,000 dollars. The construction from 1936 to date in Pennsylvania, New Jersey, New York and New England has resulted in the completion of more than half the schemes listed as necessary in the comprehensive plan which the Corps of Engineers specified to meet the provisions of the 1936 Act. There are five main river systems in the area of the flood damage. From west to east they are the Susquehana, Delaware, Hudson, Housatonic and Connecticut. Relatively little damage was caused in the areas drained by the main rivers, except for the Delaware. The most serious destruction occurred in the valleys served by tributaries where only a few flood prevention schemes had been completed.

Because of the intensity of storms in recent years there is now some doubt that the completed projects are adequate. To resolve these doubts, the Corps of Engineers, in co-operation with the U.S. Weather Bureau, is now undertaking hydrological studies. These are designed to ascertain the intensity and duration of rainfall in various catchment areas during severe storms and how long it takes for the water to reach the various streams and rivers in the area. Even if all the projects listed in the comprehensive plan had been completed before hurricane "Diane" left her watery residue, there is doubt whether all damage could have been averted. The reason for this is that long-range flood control planning is not designed to meet the threat of a flash flood. This, essentially, is what occurred in the wake of the hurricane. Normal flood controls are put upstream, near the headwaters of rivers. Here they can catch the spring run-off and prevent the slow but massive accumulation of water in the main stream before it gets down to urban areas. But the most recent flood was not the result of water flowing from small tributaries into the main stream so much as of water that fell near urban areas and cascaded down hillsides and streets until it reached the river level and piled up. Measures needed to cope with such a situation, and the cost of such projects, are engaging the attention of the Corps of Engineers. It is expected to have some recommendations on the subject for the President and Congress next year. One question that must be resolved in planning works is the probability of another flood of the same dimensions. To prevent a repetition of the destruction, thousands of miles of dykes long the banks of the smaller streams might be required. It is a serious question with some engineers and public officials whether the hazard would warrant the outlays and dislocations. The construction of dykes and emergency reservoirs along industrialised and heavily built up stretches of river can be enormously expensive and can run into strong local opposition. For one thing, the cost of the property needed is likely to run high. For another, many industries feel that they need the direct access to the streams along which they are situated. Until the U.S. Army Corps of Engineers completes its studies, it is impossible to estimate the cost of schemes to cope with a repetition of the conditions in the wake of hurricane "Diane." But, whatever the cost, it is certain that Congress will be under heavy pressure to vote larger appropriations to speed the completion of the existing programme.

Nuclear Power Demonstration at Arco, Idaho

ELECTRICITY, produced from nuclear energy, was recently used to furnish light and power for a town in the United States. Arco, Idaho, became the first community in the country to receive its entire supply of power from a nuclear source when, on July 17, 1955, electricity produced in an experimental nuclear power plant operated at the U.S. Atomic Energy Commission's National Reactor Testing Station, twenty miles away, was fed into transmission lines supplying the small town. When the reactor power was cut in, utility lines supplying conventional power to Arco from the Utah Power and Light Company were disconnected. The entire community of 1200 inhabitants then depended solely on nuclear power for more than one hour. A motion picture record of the demonstration was presented to the delegates at the recent International Conference on Peaceful Uses of Atomic Energy, at Geneva.

The experimental nuclear power plant, known as "Borax," short for "Boiling Reactor Experiment," was also the subject of a technical paper presented to the conference by Dr. Walter H. Zinn, Director of the Argonne National Laboratory. The plant, which generates more than 2000kW, was designed and constructed by the Laboratory. The reactor for the nuclear power plant has been under development by the Labora-

tory since 1953. An experimental facility for conducting studies on a reactor of this type was constructed at the testing station site in the summer of 1953 and tests on safety and steady state operating characteristics were conducted. The tests were sufficiently encouraging so that additional studies were made in the summer of 1954. Experience gained during the operation of this reactor warranted the addition of a turbo-generator so that the steam being produced could be converted into a more usable form of energy. This generating plant was placed in operation on June 28, 1955, and the production of electricity is continuing on a routine basis. The reactor consists of a pressure vessel containing an assembly of enriched uranium-bearing plates submerged in water, together with a number of neutron-absorbing rods. The water circulates through the reactor core by natural convection. Steam, produced by the heat created by the fissioning of uranium atoms, is conducted to the 3500kW turbo-generator, which is situated in a nearby building. The simplicity of construction, ease of operation, low cost, and high degree of safety suggest the possibility that this small power plant may be suitable for use in remote areas or in conjunction with mining or manufacturing operations.

Award of Elliott Cresson Medal to British Scientist

DR. F. P. BOWDEN, Reader in Physical Chemistry at the University of Cambridge, is to be this year's recipient of The Franklin Institute's Elliott Cresson medal. The medal is awarded for discovery or original research, adding to the sum of human knowledge, and for the invention of methods or products, or unusual skill or perfection in workmanship. The award, which is to be made at the Institute's Annual Medal Day ceremonies on October 19th, is to be given to Dr. Bowden for " his extensive experimental investigations which combine simplicity and clarity, and for his findings regarding the detailed nature of the processes involved when one metal slides over another." Dr. Bowden is Head of the Research Laboratory for the Physics and Chemistry of Surfaces at Cambridge. In his studies Dr. Bowden first turned his attention to the contact between solid surfaces. He showed that however carefully surfaces are prepared they are generally covered with asperities large compared with atomic dimensions. When such surfaces are placed together, they touch at the tips of these asperities which crush down until they are large enough to support the applied load. The area of real contact is thus independent of the size of the bodies and is proportional to the applied load ; it is usually only a minute fraction of the geometric size of the bodies. The second point brought out by his work is that at the regions of real contact strong adhesion occurs. The resulting friction arises from the shearing of the welded junctions formed at these points and to a lesser extent from the ploughing of one metal through the other. In addition Dr. Bowden has shown that because the area of true contact is so small the work done in overcoming friction, which appears as heat, can raise the temperature of the local contact points to extremely high values even though the bulk of the bodies remains cold. In many cases surface melting may be produced and this plays a fundamental part in many sliding processes such as polishing and the surface flow of solids. Frictional hot-spots may also play an important part, as Dr. Bowden has shown, in the initiation of chemical reactions.

American Afterburners for Use in British Jet Engines

THE Solar Aircraft Company, of San Diego, California, has entered a contract with the Bristol Aeroplane Company, Ltd., of Bristol, concerning the design of jet engine afterburners. The agreement covers Bristol's use of Solar's developments in afterburner design ; advising the British company on afterburner design and production problems ; and the immediate designing and building, at San Diego, of prototype afterburners for Bristol engines. The present agreement is for an eight-year term, calling for engineering collaboration and assistance from Solar to Bristol during that period.

Automatic Machine for Potting Electronic Components

AN automatic machine for potting electronic components has been developed and built at the National Bureau of Standards, Washington, D.C. The machine feeds a casting resin and a catalyst from heated tanks through proportioning pumps into a mixing chamber. After the liquids are thoroughly stirred, they are permitted to flow into the electronic assembly. Since the series of operations is continuous, resin can be mixed as needed, and the pot-life requirements of the resin-catalyst mixture are reduced to a minimum. Although the machine was originally designed for laboratory use, it has now also been found advantageous in production-line applications.

A rapidly growing use for casting resins is in the potting of electronic components and subassemblies which must be capable of enduring extreme environmental and handling conditions. Such units are potted to protect them against moisture, heat, pressure, shock and vibration, arcing between components, and long periods of storage under adverse conditions. Casting resins, which are simply a catalyst and a resin mixed in correct proportions, are now being used extensively to meet these conditions. However, the pouring life or pot life of certain of these mixtures is very short, sometimes only a few minutes. This short pot life requires small batch mixing operations that are wasteful in both time and materials. The development of an automatic mixing machine has overcome this difficulty.

The potting machine (Figs. 1, 2 and 3) consists of three systems—a heating system, a resin-catalyst mixing system, and a purging system.

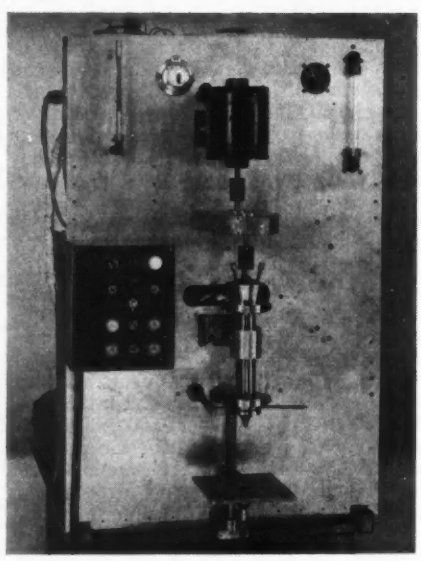


Fig. 1—Control panel, mixing chamber and stirrer drive of automatic potting machine

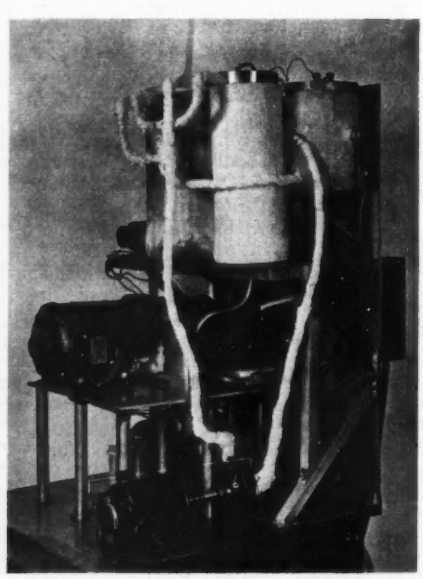


Fig. 2—Resin and catalyst tanks and metering pumps at rear of automatic potting machine

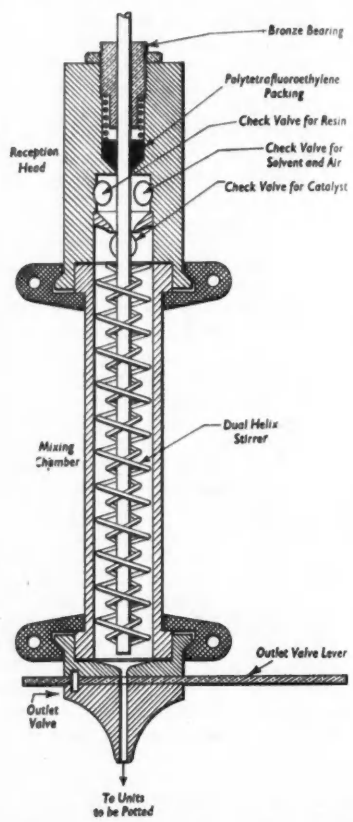


Fig. 3—Diagram of mixing chamber and stirring mechanism

The three systems are co-ordinated by manually operated switches. The heating system maintains the resin and catalyst at elevated temperatures in order to reduce viscosity and to speed levelling in the potted unit. A centrifugal pump circulates water through a tank containing an immersion heater and through coils in the resin and catalyst storage tanks. Liquids with higher boiling points may be substituted for water where required by a particular resin.

The resin and catalyst, heated by the circulating water, flow from the reservoir tanks through 120 mesh screens to the suction sides of two proportioning gear pumps whose volume output is controlled by the speed of the metering gears. The pumps are driven by a single motor through a gear train at the speeds required to give the desired volumetric ratio of resin to catalyst. The liquids flow from the pumps to spring-loaded check valves in the reception head of a mixer. The valves are opened by the pressure imparted by the pumps to the liquids, which then enter the mixing chamber. The mixing chamber is a small tube having a large length-to-diameter ratio and containing a dual-helix stirrer. The outer portion of the stirrer is a right-

hand helix, and the inner portion is a left-hand helix. The assembly is driven by a small motor. A gear reduction box between the motor and mixing chamber provides the desired stirrer speed. The stirrer shaft is enclosed in a bronze bearing with polytetrafluorethylene packing. The machine continuously mixes resin and catalyst as they are required, with only a small volume of the liquid in the mixing chamber at any given time. Continuous operation alleviates the problem of working with premixed batches which have very short pot lives, since the mixture does not have sufficient time to harden before being used.

A purging system is built into the machine to clean thoroughly all areas with which the mixed resin and catalyst have been in contact. It is used whenever the machine must stand idle longer than the pot life of the mixture. Purging consists of two operations—flushing solvent through the mixing chamber and blowing warm air through the chamber to evaporate the remaining solvent. A solvent for the resin mixture is stored in a small tank mounted on the machine. A small centrifugal pump forces the solvent into the mixing chamber when the appropriate switches on the control panel are operated ; at the same time, the flow of resin and catalyst is stopped. The solvent flushes the resin mixture out of the chamber through the outlet valve. The amount of solvent used for a complete flushing varies, but usually not more than three or four times the volume of the mixing chamber is required. After the chamber is purged of resin, the drying system is turned on to evaporate any remaining solvent. The system consists simply of a small centrifugal blower which forces air over a set of heating elements and into the mixing chamber. At the end of the purging cycle the machine is free of any solvents that might inhibit the polymerisation of the resin, and is again ready for operation.

The machine is put into operation by first closing a master switch that controls the immersion heater. When the resin and catalyst are at the proper temperature, the stirrer switch is closed ; it remains closed throughout the mixing and purging cycles. The stirrer is stopped momentarily, however, to prevent air from being stirred into the incoming mixture while the mixing chamber is first being filled. When the chamber is full, the stirrer goes back into operation. After the constituents are mixed, the machine is ready to deliver a homogeneous mixture of resin and catalyst at the desired temperature and proportions. The operation then becomes a continuous one, and the casting mixture flows through the outlet valve whenever it is opened.

The units to be potted are supported on an adjustable height table while they are being filled. An outlet tube from the mixing chamber enters the unit to be potted at the top and extends to the bottom, and the resin, instead of flowing down on the mass of wiring and components, is allowed to fill the unit from the bottom up, thus minimising air pockets and increasing the rate of production. The machine can easily be converted for use with multi-constituent resins by the introduction of a suitable number of tanks, valves and metering pumps.

Construction of Hampton Roads Tunnel-Bridge in Virginia

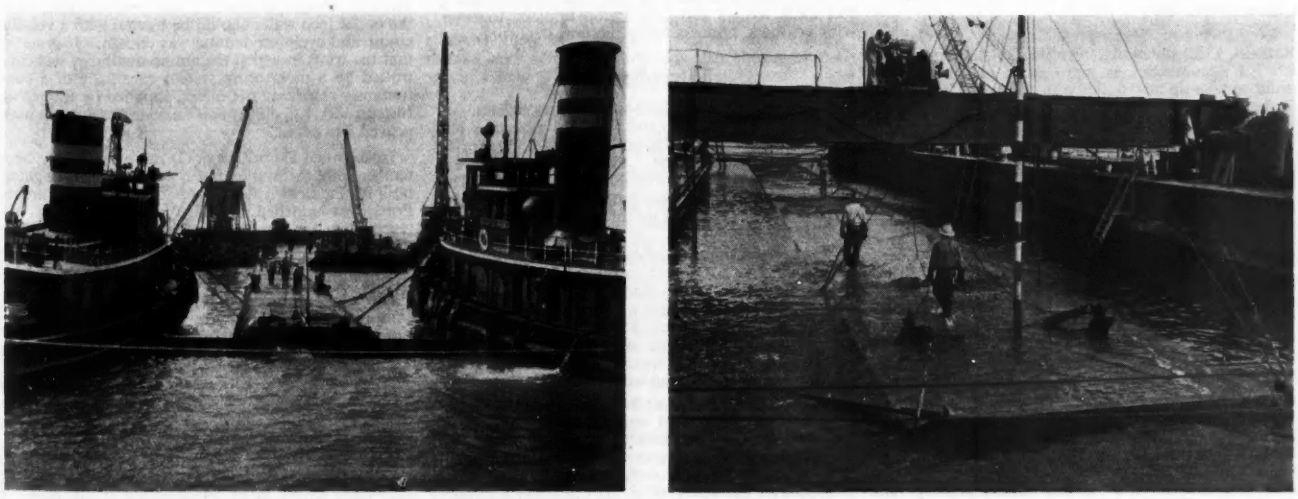
THE accompanying two illustrations show the first of twenty-three 300ft long underwater sections of the tunnel part of the bridge tunnel now under construction across Hampton Roads, Virginia, being sunk into position by the Merritt-Chapman and Scott Corporation, the general contractors on the project for the Virginia State Highway Department. Into the construction of the section have gone approximately 570 tons of structural steel used in the fabrication of its double-shelled casing and approximately 11,430 tons of concrete. Its buoyancy had been carefully calculated so that it weighed approximately 250 tons underwater as it was guided to the bottom by specially designed lowering tackle and steel framework placed across two barges, one on either side of the section.

The 6860ft long underwater part of the 3½-mile long Hampton Roads crossing is a trench tunnel, the eleventh of its kind to be built in the United States. The steel casing for the underwater part of the tunnel is being built sectionally ashore, at the Eddystone works of the Baldwin-Lima-Hamilton Corporation in Pennsylvania. The double-shelled steel sections are made water tight by bulkheads at either end, then launched like ships and towed to a "shape-up" station near the tunnel site. There, while still afloat, they are lined with an 18in interior ring of concrete and the 23ft wide roadway. Weighted by additional concrete placed between the inner ring and the outer octagonally-shaped shell, the sections are then sunk one by one in exact position in a trench, about 50ft deep by 40ft wide at the base, which has been dredged across the bottom of the Roads. After several sections have been placed and joined, the exterior joints between the sections will be sealed by pouring a tremie concrete envelope around the tube between adjacent bulkheads which are connected by sheet steel forms. During the final stages of construction, after the tunnel units are entirely covered with backfill, the bulkheads between the sections will be removed, starting at one end adjoining an approach. The joints will then be additionally sealed from the inside and finishing touches on the tunnel lining will be completed in the dry underwater. All of the twenty-three underwater tunnel sections will measure 37ft across the width of the octagonally shaped outer shell. The section now sunk went into position immediately adjacent to a man-made island situated about 3250ft from the Hampton shore. The island, together with a similar one being built about 6110ft from Willoughby Spit, near Norfolk, will link the tunnel with reinforced concrete low-level approach bridges extending out from each shore.

Weighted down to a point approaching negative buoyancy, the tube was barely awash as the operations started. With the tube section in position, approximately 240 tons of concrete, mixed on one of the barges, were pumped through tremie pipes and placed into open "pockets" between the inner and outer shells of the tube. The section, supported by the special lowering facilities resting on the barges and attached to plate shackles built into the top of the section, was then gently lowered until it came to rest on the specially prepared gravel base at the bottom of the trench, about 50ft below the water surface at the southern end of the section. As it went down, engineers maintained transit sights on the masts to ensure that the section remained in absolute alignment. As the tunnel section came to rest on the bottom, additional instrument readings were taken to determine that the grade and alignment were correct. The Hampton Roads tunnel will have a maximum grade of 4 per cent and will be about 113ft below the water surface at the deepest point.

With the tube at final grade and alignment on the bottom, more concrete is placed in the pockets for additional ballast, resulting in a negative buoyancy of 450 tons. Sand will then be chuted by pipe from a derrick barge until the tube is firmly embedded up to the first "knuckle" of the outer octagonally shaped shell. Additional sand will then be placed over the middle of the tube section, keeping the end clear for connection to the next section. Three of the other twenty-three sections to be used in the construction of the tunnel are now at the contractor's "shape-up" pier at Lamberts Point in Norfolk, in various stages of interior concreting.

MEETING OF U.S. ATOMIC FORUM.—Industrial and international developments in atomic energy provided the theme for the third Atomic industrial forum and the first American atomic industry trade fair which were held concurrently in Washington this week from September 27th to 29th. At the forum discussions were held on power and research reactors, the use of radioactive isotopes, and the commercial development of atomic products. A review was given of papers presented at the Geneva "Atoms for Peace" conference and reports were presented on atomic energy activities in Great Britain, Belgium, Canada, France and the U.S.A. Exhibits from more than 70 American firms were seen at the trade fair.



300ft underwater tunnel section being towed into final position across Hampton Roads and (right) the section being sunk into dredged trench

Personal and Business

Appointments

MR. JOHN TAYSON has been appointed works director of Cimex-Fraser Tuson, Ltd., Orpington, Kent.

MR. C. E. BLUNT and Mr. J. A. GRACE have been elected directors of Folland Aircraft, Ltd., Hamble, Southampton.

MR. ARTHUR H. ELLIOTT has been appointed executive vice-president and general manager of Iricon Agency, Ltd.

MR. K. W. WATKINS has been appointed project engineer by the Hymatic Engineering Company, Ltd., of Redditch, Worcs.

SIR ERIC SPEED, K.C.B., has been appointed to the British board of Engelhard Industries, Ltd., 52, High Holborn, London, W.C.1.

SIR JOHN WRIGHTSON, Bt., and Mr. PETER WRIGHTSON have been appointed managing directors of Head, Wrightson and Co., Ltd., Thornaby-on-Tees.

MR. ORLANDO OLDHAM and Mr. Peter James Brocklehurst have been appointed to the board of directors of Oldham and Son, Ltd., of Denton, Manchester.

THE LONDON TRANSPORT EXECUTIVE announces the appointment of Mr. A. H. Grainger as deputy chairman, following the retirement from that office of Mr. John Cliff.

THE MOND NICKEL COMPANY, Ltd., states that Dr. W. Steven has been appointed superintendent of the development and research department laboratory in Birmingham, in succession to the late Mr. Howard Evans.

THE MINISTRY OF SUPPLY announces the appointment of Dr. W. B. Littler as principal director of scientific research (defence) in succession to Dr. Cawood, who is to become principal director of scientific research (air).

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., announces the following appointments :—Mr. D. B. Clark, A.M.I.E.E., assistant manager, Glasgow office, and Mr. A. L. Fuller, A.M.I.E.E., assistant manager, London office.

C.A.V., Ltd., Acton, announces the appointment of Mr. P. G. Ware, A.R.Ae.S., M.S.A.E., as chief engineer (electrical), and in this post he will be responsible for the technical direction of electrical engineering design and development.

MR. E. R. WILKINSON, M.I.Mech.E., M.I.E.E., is relinquishing his post as commercial manager, Central Electricity Authority, at the end of the year, to join the boards of Power Securities Corporation, Ltd., and of Balfour Beatty and Co., Ltd.

THE PLESSEY COMPANY, Ltd., announces that Mr. A. E. Underwood has been appointed to the board. Mr. Underwood joined the company in 1948. He was appointed an executive director in 1951 and a director of Plessey International, Ltd., in January, 1954.

THE NORTH OF SCOTLAND HYDRO-ELECTRIC BOARD states that Mr. Angus A. Fulton, M.I.C.E., M.I.Mech.E., has been appointed general manager in succession to the late Mr. Thomas Lawrie. Mr. Fulton has been the Board's chief hydraulic and civil engineer since 1944.

INTERNATIONAL HARVESTER COMPANY OF GREAT BRITAIN, Ltd., states that Mr. George A. Tomik has left his appointment as manager of engineering in order to take up new duties with the parent company in the U.S.A. His successor as manager of engineering is Mr. R. I. Birkholz.

MR. FRANK J. CRABB, B.Eng., M.I.C.E., F.R.S.H., is shortly relinquishing his post as Principal Scientific Officer with the Department of Scientific and Industrial Research (Building Research Station) and is taking up an appointment with the British Standards Institution of 2, Park Street, W.1.

MR. A. H. KENYON, M.I.E.E., has been elected Chairman of the North-Eastern Centre of the Institution of Electrical Engineers for 1955/56 in place of Mr. D. E. Lambert, who has tendered his resignation on assuming a new appointment which will take him from the area of the North-Eastern Centre.

G. AND J. WEIR, Ltd., Glasgow, announces the appointment of Dr. A. M. Baxter, M.Sc., as head of the research department. Dr. Baxter, who is at present the senior lecturer in the department of Civil and Mechanical Engineering, Royal Technical College, Glasgow, served his apprenticeship at Weirs and was awarded the Parsons Scholarship by the Institution of Naval Architects, graduating B.Sc. with honours in 1936.

THE BRUSH GROUP, Ltd., states that Mr. M. C. Clear is to become managing director of its export companies (Associated British Oil Engines, Ltd., Brush Exports, Ltd., and National Oil Engines, Ltd.), in addition to his existing appointment as sales director of the group. Mr. G. N. Bridge is to be London manager of the export companies. These appointments will take effect on November 1st and are consequent upon the resignation of Mr. J. P. Ford, who is joining the board of Charles Colston, Ltd.

ACHESON COLLOIDS, Ltd., 18, Pall Mall, London, S.W.1, states that Mr. K. Clark, formerly technical sales representative in North-East England, has been transferred to the branch office at Richmond, Surrey, where he will take responsibility for sales development in the home counties. Mr. A. D. Wright has been appointed assistant sales manager, Mr. C. F. Clark has been appointed technical sales representative at Richmond, and Mr. M. C. Lively has been appointed to the London office to be responsible for overseas sales development.

Business Announcements

THE INSTITUTION OF MINING ENGINEERS has changed its address to 3, Grosvenor Crescent, London, S.W.1 (telephone, Belgravia 3691).

THE ASSOCIATION OF BUILDING TECHNICIANS states that its address is now 1, Ashley Place, London, S.W.1 (telephone, Victoria 0447).

THE BRITISH STANDARDS INSTITUTION has opened a sales office at the headquarters of the Birmingham Chamber of Commerce, 95, New Street, Birmingham.

THE INDIA RUBBER, GUTTA PERCHA AND TELEGRAPH WORKS COMPANY, Ltd., Herga House, Vincent Square, London, S.W.1, states that its name will be changed on October 1st to Silvertown Rubber Company, Ltd.

POWER-SAMAS ACCOUNTING MACHINES, Ltd., is taking over, on a lease from Brockhouse Engineering (Southport), Ltd., a works, with 200,000 square feet of space, at Southport, Lancs, for the production of punched card accounting machines and equipment.

TUBE INVESTMENTS, Ltd., announces that Sir George Briggs has resigned from the board of Tube Investments, Ltd., and has relinquished his appointments with the subsidiary companies of the Group. Sir George will still be available to Tube Investments, Ltd., in a consultative capacity.

MR. FRANCIS PHILIP LAURENS, O.B.E., M.I.Mech.E., has been appointed managing director of Powers-Samas Accounting Machines, Ltd., as from October 24, 1955. Mr. Laurens will retain his seat on the board of Vickers-Armstrongs, Ltd., but will relinquish his offices of deputy managing director of Vickers-Armstrongs (Engineers), Ltd., and general manager of the Barrow works of that company. He will also relinquish his seats on the boards of Vickers-Armstrongs (Engineers), Ltd., and Vickers-Armstrongs (Shipbuilders), Ltd.

Contracts

RICHARD SUTCLIFFE, Ltd., Horbury, Wakefield, has received an order from Imperial Chemical Industries, Ltd., for the supply and erection of a coal handling plant at Billingham on Tees. The equipment to be supplied includes five 36in wide belt conveyors, two plate feeders and two wagon tipplers, together with crushers, hoppers and structural steelwork.

Miscellanea

BIBLIOGRAPHY OF TECHNICAL DICTIONARIES.—A bibliography of monolingual technical glossaries has been published for "Unesco" by H.M.S.O. (price 14s. 6d.), as part of the "Unesco" series on the documentation and terminology of science. The bibliography contains details of glossaries in twenty-seven languages covering technical subjects, especially applied sciences.

MOBILE OFFICES.—Mobile site offices having lengths of 12ft or 16ft, and a width of 7ft 6in, are now made by George Cohen Sons and Co., Ltd. They have a heavy duty chassis with 3in by 1½in channel side members reinforced at the wheel arch, and ½in by 2in by ½in angle iron cross members, all welded. The body is coach built with a timber frame and covered shiplap weatherboarding.

CANADIAN ENGINEERS IN BRITAIN.—It is announced that thirty-six Canadian engineering graduates are now arriving in the United Kingdom to take up Athlone Fellowships awarded by the British Government. The Athlone Fellowship scheme was instituted in 1951 with the object of giving Canadian engineers who have recently graduated opportunities of learning about British engineering and technical methods. The scheme is administered by a managing committee under the chairmanship of Sir Arthur Fleming and is representative of the Board of Trade, which provides funds for the scheme, industry, the universities, the Ministry of Education, the Commonwealth Relations Office, and the British Council. The awards are for two years and thirty-eight are made each year.

AIRCRAFT AND EQUIPMENT.—The Martin-Baker Aircraft Company, Ltd., Higher Denham, Nr. Uxbridge, Middlesex, has produced a record of its activity since 1929 in the form of a generously illustrated loose-leaf book. It records the five prototype aircraft built of steel tube on the system associated with the firm, and proceeds to detail the various types of aircraft equipment originated or constructed by them, culminating in the ejection seat and associated training devices.

MOTOR VEHICLE STATISTICS.—The September, 1955, issue of the Society of Motor Manufacturers and Traders, *Monthly Statistical Review* includes censuses of cars, hackney vehicles and goods vehicles by counties in England, Wales and Scotland. Nearly one-tenth of England's cars are registered in Yorkshire (242,897 in all), while the total cars in Great Britain numbered 3,099,547, among which Surrey boasted a steam vehicle and Warwickshire two gas turbines. The grand total of hackneys was 107,596, fewer than the goods vehicles registered in London, the only county to reach six figures. The totals of goods vehicles were : England, 893,687 ; Wales, 47,084 ; Scotland, 92,097.

DEATH OF MR. EDMUND SAYERS.—We record with regret the death, on September 20th, of Mr. Edmund Sayers, formerly of British Thomson-Houston Company, Ltd. He was aged seventy. It was in 1905 that he joined his elder brother in the service of B.T.H., and until 1914 specialised on meters and instruments. Henceforward he worked on magnetos and other aircraft and automobile accessories. He became manager of the company's aero equipment and sales department before retiring with forty-eight years' service to the firm. Sayers was a Freeman of the City of London, and Liveryman of the Worshipful Company of Coachmakers and Coach Harness Makers. He is survived by his wife and son.

DROP FORGINGS IN ALLOY STEELS.—A colour film entitled "Drop Forgings in Alloy Steels," has been made by the photographic section of the Firth-Brown Research Laboratories for Firth-Derihon Stampings, Ltd., and was recently shown for the first time in London. After a brief introduction, showing the firm's works and range of products, the film deals with the production of selected types of drop forgings—from the steel bar or billet to the finish machined component. It shows the various stages in the production of gas turbine discs, helicopter rotor assemblies, gas turbine rotor blades in "Nimonic" nickel-based alloys, and a number of other drop forgings for special applications in various industries.

BOILER SCALE FORMATION.—Investigations carried out by the "Alfloc" Water Treatment Service of Imperial Chemical Industries, Ltd., suggested that the boiler trouble on board tankers of the fleet of the Esso Petroleum Co., Ltd., was caused by corrosion of steel cargo heating coils and pick-up of copper in the ships' feed systems. To ensure that the condensate remains alkaline it was recommended that the boiler feed water should be treated with a volatile amine and cyclohexylamine was chosen. It is stated that the trials in which the amine treatment was controlled by a monitoring system consisting of a continuously recording pH meter, supplied by Electronic Instruments, Ltd., and other ancillary equipment have proved successful.

IMMINGHAM DOCK OUTER GATES.—On Friday, September 16th, the first leaf of a new pair of lock gates, built for the British Transport Commission's, Humber Ports, was launched. Head, Wrightson and Co. was responsible for the design, fabrication and building of the gates to the Commission's specification. After launching, tugs were waiting to tow the gate to Immingham, where it will be stepped into position. These gates are for the 90ft wide outer entrance of Immingham Dock and are of all welded construction. Each leaf consists of a mild steel framework of vertical end heel and mitre posts, with seventeen horizontal plate decks enclosed by mild steel skin plates. There is a central watertight bulkhead and two off-centre diaphragms, constructed in fitted panels between the decks. The approximate overall dimensions of each leaf are 54ft by 50ft 3in by 8ft, and the approximate weight of each leaf is 190 tons. The new welded gates replace a pair of riveted wrought iron gates which Head, Wrightson and Co. installed in the same entrance in 1908 ; the new welded design effects an approximate saving in weight of 25 per cent.

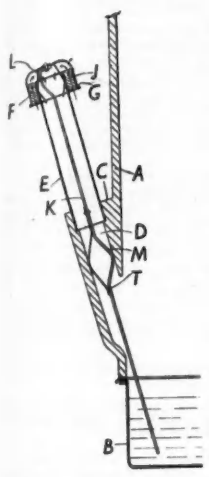
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

INTERNAL COMBUSTION ENGINES

734,540. September 25, 1952.—A DIP-STICK AND AIR FILTER ASSEMBLY, Cooper's Mechanical Joints, Ltd., 14, Liverpool Road, Slough, and Stanley Paul Witchell, 22, Woodland Crescent, Llanfoist, Abergavenny.

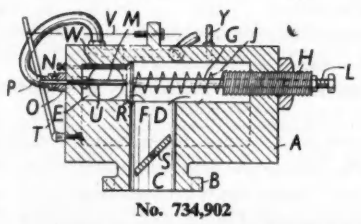
In the drawing, a crankcase casting *A* is shown, formed on one side, some distance above the sump *B*, with a lateral shoulder *C* through which extends a conduit *D* which is extended upwards by a rigid tube *E*, at the top of which the closure member is mounted. This closure member has a cap *F* with a flat top and a flanged skirt. The flange at the bottom of the skirt is doubled inwards to retain a circular flange formed at its centre with a sleeve through which the tube passes and is a neat sliding fit. The upper end of the sleeve is formed with a narrow internal flange that rests on the top of the tube and lies somewhat below the top of the cap so as to provide a space between the cap and tube when the closure member is fitted. A cylindrical mass *J* of filtering medium in the form of knitted wire mesh is inserted into the space between the sleeve and skirt, and the flange at the bottom of the sleeve is perforated to form the breather passage. The dip-stick *K* is formed from a flat bar which is bent at the top and riveted. A double leaf spring *L* through which the rivet passes bears against the inner surface of the tube to hold the cap securely in place. To steady the dip-stick against vibration, it has at its centre an undulation *M*, the centre of which bears against one side of the conduit *D*, while the centre of a similarly shaped leaf-spring bears against the opposite side of the conduit *D*. The dip-stick is marked with three graduations, "full," "add oil" and "low."—*August* 3, 1955.



No. 734,540

734,902. July 22, 1953.—CARBURETTORS, James Alan Gordon, 679, Chorley New Road, Horwich; and Samuel John Hodgkiss, 8, Marlborough Street, Bolton.

As the drawing shows, the carburettor consists of a housing *A* attached to the engine induction manifold by the flange *B*. An air inlet pipe *C* communicates with the induction manifold and with the transverse chamber *D*. This chamber communicates with a further chamber *E* through a mushroom valve *F*. The spring-loaded valve spindle *G* slides in a sleeve



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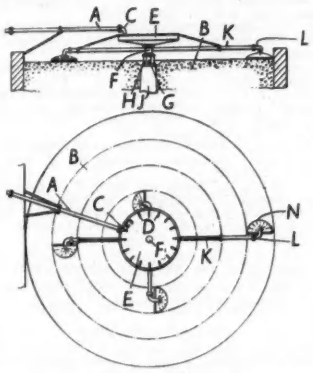
H. The guide sleeve is screwed through the housing and the tension in the spring *J* is adjusted by altering the position of the sleeve. The outer end of the sleeve is screwed to receive an adjustable stop and locknut *L* to regulate valve movement. The valve *B* carries a tapered needle *M*, which enters an orifice *N* in a jet or nozzle *O*, communicating with the fuel supply pipe *P*. As the valve opens the needle is withdrawn and fuel enters the chamber *E* and mixes with the air and passes through the valve to the chamber *D*. Fuel is supplied through the jet by gravity, or a constant-pressure pump, and is controlled by the needle valve *M*. The fuel-air mixture passing into the manifold is controlled by the butterfly valve *S*. The wider the valve opening the lower the pressure behind the valve *F*, allowing a greater volume of fuel and air to pass. The spring *J* closes the valve *F* as the throttle butterfly valve *S* is closed, thereby enabling a correct mixture strength to be maintained over the throttle range. A lever *T*, shown to the left of the drawing, is pivoted on the housing and engages a rod *U* which serves to lift the valve *F* off its seat during starting from cold, thereby allowing additional fuel and air to pass to the manifold. As shown, the lever may be operated by a wire *V* from the engine dashboard. A second rod *W* may extend through the housing and be screwed to engage the valve *F*. This rod may be set to prevent the valve from completely closing and form a slow-running control. A supplementary fuel supply for starting may be introduced into chamber *D* through a pipe *Y*.—*August* 10, 1955.

CIVIL ENGINEERING

734,686. August 5, 1952.—ROTARY DISTRIBUTORS FOR FILTER BEDS, Cyril John Hartley, Cae Brest, The Avenue, Harpfields, Stoke-on-Trent.

The invention relates to rotary distributors for filter beds for the purpose of distributing sewage or other effluent as evenly as possible over the filter surface. The invention is not confined to any particular way of feeding the liquid to the distributor, but it is preferably fed at intervals by a tipping bucket, pumping system, or other known means. As shown in the drawing, a feed pipe or trough *A* extends horizontally over the filter bed *B* from the side to the centre. The end of the pipe or trough is bent over at an elbow *C* to cause the discharged



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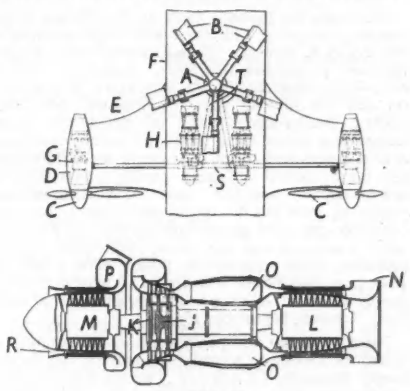
liquid to impinge on vanes *D* in a circular pan *E* to assist in its rotation. The pan is mounted on a rotating hollow column or barrel *F* which is carried by a bearing *G* within a housing *H* and supported on a concrete pillar *J* in the centre of the filter bed. The liquid thus delivered into the pan *E* flows out through tubular arms *K* which extend radially outwards from the column. These arms are of different lengths, and the number of them will vary according to the diameter of the filter bed. As shown in the drawings, there are four spaced radially at equal angles. The outward end region of each arm is bent or curved round approximately at right angles to the length of the arm, as shown at *L*, and there is a single jet hole in the outer extremity of the bend which discharges at right angles to form a jet which, in conjunction with the effect of the vanes *D*, propels the distributor; in some cases the jets are the sole propelling medium. In the drawing the bend *L* is mainly horizontal and is curved downwards at the end to discharge the liquid on to a spreader plate *N*. Modified designs of discharge nozzles and spreader plates are also shown in the specification.—*August* 3, 1955.

AERONAUTICAL ENGINEERING

735,106. January 2, 1952.—HELICOPTERS, The Fairey Aviation Company, Ltd., North Hyde Road, Hayes, Middlesex. (*Inventor: Archibald Graham Forsyth.*)

The invention relates to helicopters having a jet-driven rotor and at least one horizontal propeller, and is concerned with the layout of the power units. As the drawing shows, the rotor column *A* supports a five-bladed rotor *B* provided with pressure jet units, designed to burn fuel in a supply of air received from outside the unit under pressure. For forward propulsion, two propellers *C* are mounted in nacelles *D*, at the ends of a pair of stub wings *E*. Each propeller has its axis fore and aft driven by a fuel-burning pressure gas turbine *G* designed again to burn fuel in a supply of air received under pressure from outside the unit. The compressed air for both the rotor pressure jet units *B* and the propeller turbines *G* is supplied by a pair of turbo-compressors *H* mounted side by side in the fuselage *F*. As will be seen in the lower view, there are two rotors *J* and *K*; the rear one *J* drives a compressor *L* supplying both turbine rotors, while the front turbine rotor *K* drives another compressor *M*, providing air for the turbines *G* driving the propellers *C*. Combustion air is drawn in through an annular chamber *N* at the rear and compressed in the compressor *L* before being delivered to the combustion chambers *O*. The products of combustion drive the two-stage turbine rotors *J* and *K*. The rotor *J* drives the axial-flow compressor *L*. From the rotor *J* the products of combustion pass forward to drive the separate free turbine rotor *K*, which constitutes the third stage. This rotor drives the forward compressor *M* at the front end of the unit, which takes in air from a forward facing annular inlet *P*, which opens into the delivery chamber *R*, delivering air into the distributing ducts *S* forming a part of the delivery system; the outputs from the two compressors *H* are connected to the turbines by a common



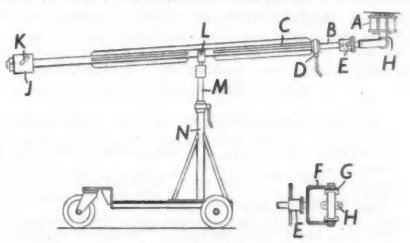
No. 735,106

duct *T* as shown; throttle valves between the compressors *H* and the delivery ducts *T* are provided to close off one or both ducts as required. Compressed air for the rotor jets is led through separate ducts from each compressor to the rotor column *A*, where the two ducts merge into one. Throttle valves are again provided in the ducts. Thus, by manipulation of the four throttling devices, it is possible to deliver the whole of the air to the rotor or to the propeller turbines, or to distribute it between the two in a proportion that can be varied continuously. Should one compressor *H* fail or break down, then the air from the other compressor can be similarly distributed to the rotor and the forward propellers, and the proportion delivered to the propeller turbines equally divided, so that they both develop equal thrust, and it is not necessary to use the rudder to correct a heavy turning moment caused by one propeller acting alone.—*August* 17, 1955.

MARINE ENGINEERING

735,153. June 24, 1953.—DESCALING APPARATUS FOR SHIPS' KEELS, W. Hilliers' Scheepsclassificeer-En Verfbedrijf N.V., Sluisjesdijk 141, Rotterdam, Holland.

As shown in the drawing, the descaling device *A* is mounted at the end of a bar or tube *B* which is slidable in one end of a lever *C* and can be secured in a desired position by a clamp *D*. The outer end of the bar is formed with a socket *E* in which a fork *F* is mounted so that it can be rotated over a definite angle about the bar. The descaling device is secured on a member *H* which is pivotally secured between the ends of the fork *F* with interposed friction rings *G*. In this form the pneumatic descaling device *A* can be rotated over an angle about two axes so that the



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active surface of the device can be adapted to reach each position of the surface to be descaled. At the end of the other arm of the lever there is a weight *J* which can be secured by a clamp *K*. By displacing the weight and changing the length of the other lever arm *C* and *B*, the pressure with which the descaling device is pressed against the keel surface can be adjusted. In the middle the lever is provided with two pivoting gudgeons *L* supported by a fork on the bar *M*, which can slide in the column *N* for adjustment to the desired height. The column is supported on an underframe mounted on wheels so that the scaling device can be moved under any desired part of the ship's keel. A modified design is also shown in the specification.—*August* 17, 1955.

Launches and Trial Trips

PRESIDENT KRUGER, cargo ship; built by the Furness Shipbuilding Company, Ltd., for Northern Steamships, Ltd., Johannesburg; length overall 467ft 3in, length between perpendiculars 435ft 8in, breadth moulded 59ft, depth moulded to upper deck 39ft 2in, deadweight 11,165 tons on 27ft 9¾in Lloyd's summer draught; five holds, fifteen derricks ranging from 2-ton to 30-ton lift, electric deck machinery; two 150kW diesel-driven and one 150kW steam-driven generators, two vertical thimble-tube boilers; Hawthorn-Doxford single-acting, two-stroke, opposed-piston oil engine, four cylinders, 670mm diameter by 2320mm combined stroke, 4400 b.h.p. at 115 r.p.m. Trial September 12th.

PANAGHIA, oil tanker; built by the Furness Shipbuilding Company, Ltd., for Porto Alegre Compania Naviera S.A. Panama; length overall 593ft, length between perpendiculars 560ft, breadth moulded 80ft, depth moulded 42ft 3in, deadweight 24,800 tons on 32ft 4in summer draught, designed speed 14½ knots; twenty-seven cargo oil tanks, one main cargo pump room, three 1000 tons per hour turbine-driven centrifugal cargo oil pumps, three 150 tons per hour vertical stripping pumps; two 325kW turbine-driven generators, one 75kW diesel-driven generator, two 60kW motor generators; one set of double-reduction geared turbines built by Richardsons, Westgarth and Co., Ltd., 7300 s.h.p. at 100 propeller r.p.m., maximum power 8200 s.h.p. at 104 r.p.m., two Foster Wheeler "D" pattern boilers, supply steam at 450 lb per square inch at 750 deg. Fah. Launch, September 15th.

PIZARRO, cargo and passenger liner; built by The Greenock Dockyard Company, Ltd., for the Pacific Steam Navigation Company; length between perpendiculars 476ft, breadth moulded 66ft, depth moulded to upper deck 40ft 8in, deadweight 11,100 tons on 28ft mean draughts, gross tonnage 8560 tons; twelve passengers; three complete decks in Nos. 1, 2 and 3 holds, two decks in Nos. 4 and 5 holds; ten 5-ton, four 10-ton and one 70-ton derricks, electric deck machinery; three 260kW diesel-driven generators; one set of Parsons triple-expansion double-reduction geared turbines, 9400 s.h.p. at 108 propeller r.p.m. in service, maximum power 10,340 s.h.p., two Babcock and Wilcox water tube boilers supply steam at 415 lb per square inch and 750 deg. Fah.—Trial September 19th and 20th.

ANTINEA, oil tanker: built by the Ateliers et Chantiers de France for the Société Africaine d'Armement; length overall 590ft 7in, length between perpendiculars 557ft 9in, breadth moulded 78ft 9in, depth moulded 42ft 8in, draught loaded 30ft 2in, deadweight 21,500 tons, nineteen cargo oil tanks; trial speed 16 knots; one set of C.E.M.-Parsons double reduction geared turbines, 12,000 s.h.p.—Trial September.

CORSTREAM, self-trimming collier; built by the Burntisland Shipbuilding Company, Ltd., for William Cory and Son, Ltd.; length between perpendiculars 320ft, breadth moulded 46ft, depth moulded 22ft 4in, deadweight 4640 tons on 20ft 3in draught; five clear holds, steam deck machinery; one direct-acting, triple-expansion North-Eastern "Reheat" steam engine, 1100 i.h.p., steam supplied at 220 lb per square inch by two cylindrical boilers. Trial September.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Oct. 5th.—MERSEYSIDE SECTION: Chamber of Commerce, 1, Old Hall Street, Liverpool, 3, "Stereophonic Sound," R. A. Bull, 7 p.m.

Thurs., Oct. 6th.—N.W. SECTION: Reynolds Hall, College of Technology, Sackville Street, Manchester, "Colour Television," G. N. Patchett, 6.30 p.m.

Wed., Oct. 12th.—W. MIDLANDS SECTION: Technical College, Wulfruna Street, Wolverhampton, "Frequency Modulation Broadcasting and Reception," H. E. Farrow, 7.15 p.m.

CHEMICAL SOCIETY

Wed., Oct. 5th.—MANCHESTER BRANCH: Large Chemistry Theatre, The University, Manchester, "Inorganic Metallurgical Aspects of Atomic Energy," L. Rotheram, 6.30 p.m.

Thurs., Oct. 6th.—BRISTOL BRANCH: Chemistry Department, The University, Bristol, "The Impact of Nuclear Energy on Industry," J. M. Fletcher, 7 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Thurs. and Fri., Oct. 13th and 14th.—Conference Room, Campfield Avenue, Deansgate, Manchester. In connection with the Fuel Efficiency Exhibition (Wed., Oct. 12th, to Sat., Oct. 22nd) the Association has arranged a Conference entitled "The Cost of Steam."

DIESEL ENGINE USERS' ASSOCIATION

Thurs., Oct. 20th.—ANNUAL GENERAL MEETING: Caxton Hall, Westminster, London, S.W.1, Report for 1954: "Diesel Engines: Design for Service," C. H. Bradbury, 2 p.m.

ELECTRICAL POWER ENGINEERS' ASSOCIATION

Mon., Oct. 3rd.—NATIONAL TECHNICAL GROUPS: Tudor Room, Caxton Hall, Westminster, London, S.W.1, "Recent Developments in Solid Systems of H.T. and L.T. Distribution," E. J. Whitcher, 7 p.m.

Thurs., Oct. 6th.—MANCHESTER LOCAL GROUP: Town Hall, Extension, Manchester, 2, "H.V. H.R.C. Fuses," K. Dannenberg, 7 p.m.

ELECTRIC RAILWAY SOCIETY

Thurs., Oct. 6th.—Fred Tallant Hall, 153, Drummond Street, London, N.W.1, "Fifty-cycle Traction To-day and To-morrow," B. K. Cooper, 7.15 p.m.

ENGINEERING INDUSTRIES ASSOCIATION

Wed. to Fri., Oct. 12th to 14th.—Royal Horticultural Society's New Hall, Greycoat Street, London, S.W.1, Eighth London Regional Display.

ILLUMINATING ENGINEERING SOCIETY

Mon., Oct. 3rd.—LEEDS CENTRE: Yorkshire Electricity Board, Ferensway, Hull, "Stage Lighting," P. Corry, 7 p.m.

Wed., Oct. 5th.—NEWCASTLE CENTRE: Department of Electrical Engineering, King's College, College Road, Newcastle upon Tyne, 1, Chairman's Address, J. N. K. Rankin, 6.15 p.m.

Thurs., Oct. 6th.—GLASGOW CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "The Architect and the New I.E.S. Code," A. Buchanan Campbell, 6.30 p.m.——NOTTINGHAM CENTRE: E. Midlands Electricity Board, Smithy Row, Nottingham, Chairman's Address, P. A. Moore, 6 p.m.

Mon., Oct. 10th.—SHEFFIELD CENTRE: Medical Library, The University, Western Bank, Sheffield, 10, Chairman's Address, W. Berry, 6.30 p.m.

Tues., Oct. 11th.—SESSIONAL MEETING: Royal Institution, Albemarle Street, London, W.1, Presidential Address, A. C. Higgins, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Sept. 30th.—BIRMINGHAM BRANCH: Imperial Hotel, Birmingham, "The Do's and Don'ts of Refrigeration," Malcolm E. Lea, 7.30 p.m.

Tues., Oct. 4th.—LONDON BRANCH: Royal Society of Arts, John Adam Street, Adelphi, W.C.2, "Air Pollution Problems and their Cure," J. B. M. Mason, 7 p.m.

Wed., Oct. 5th.—SOUTHAMPTON BRANCH: Grand Hotel, Bournemouth, "Modern Trends in Heating and Ventilating," Colonel Concannon, 7.30 p.m.

Thurs., Oct. 6th.—MERSEYSIDE AND N. WALES BRANCH: Royal Institution, Colquitt Street, Liverpool, "Statutory Requirements in Connection with Boilers and Pressure Vessels," G. A. Anderson, 7.15 p.m.——PETERBOROUGH BRANCH: Campbell Hotel, Bridge Street, Peterborough, "Gas Turbines in Industry," J. R. Needham, 7.30 p.m.

Tues., Oct. 11th.—MANCHESTER BRANCH: Engineers' Club, Albert Square, Manchester, "Steam for Process," L. G. Northcroft, 7.15 p.m.

Wed., Oct. 12th.—E. MIDLANDS BRANCH: County Hotel, Theatre Square, Nottingham, "Planned Maintenance," A. S. Stedman, 7 p.m.——LEICESTER BRANCH: College of Art and Technology, The Newarkes, Leicester, "Works Accountancy," D. D. Eade, 6.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Tues., Oct. 4th.—SLOUGH SECTION: High Duty Alloys, Ltd., Slough, "Pattern Making," 7.30 p.m.

INSTITUTE OF FUEL

Tues., Oct. 4th.—MIDLAND SECTION: Midlands Electricity Board's Lecture Room, Kingsway, Stoke-on-Trent, "National Fuel Resources in the Light of National Fuel Requirements," G. E. Foxwell, 7 p.m.

Wed., Oct. 5th.—LONDON SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1, "The Effect of Coal Quality on the Efficiency of a Shell Boiler Equipped with a Travelling-Grate Stoker," E. J. Macdonald and M. V. Murray, 5.30 p.m.——YORKSHIRE SECTION: Royal Victoria Hotel, Sheffield, Chairman's Address, H. E. Pearsall, 2.30 p.m.

Fri., Oct. 7th.—S. WALES SECTION: S. Wales Institute of Engineers, Park Place, Cardiff, "Implications of the Rivers (Prevention of Pollution) Act, 1951," A. H. Williams, 6 p.m.

Mon., Oct. 10th.—N.E. SECTION: Visit to Fishburn Coking Plant, 2.30 p.m.——Chemistry Lecture Theatre, King's College, Newcastle upon Tyne, "Coal Preparation and Evaluation," J. K. Matthews, 6.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Oct. 4th.—85, Minories, London, E.C.3, Presidential Address, "The Century in Which We Live," H. A. J. Silley, 5.30 p.m.

Tues., Oct. 11th.—85, Minories, London, E.C.3, "Passenger Liner with Engines Aft," R. K. Craig, 5.30 p.m.

INSTITUTE OF PETROLEUM

Wed., Oct. 5th.—STANLOW BRANCH: Grosvenor Hotel, Morecambe, "Development of Oil Cracking as a Source of Raw Materials for the Polymer and Plastics Industry," J. W. Woolcock, 8.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Oct. 3rd.—SCOTTISH CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Gas Turbine Development for Road Transport," D. A. Phillips, 7.30 p.m.

Tues., Oct. 4th.—EASTERN CENTRE: Golf Hotel, Ipswich, "Maintaining a Mixed Dispersed Fleet," W. L. Gage, 7 p.m.

Wed., Oct. 5th.—E. MIDLANDS CENTRE: Mechanics Institute, Nottingham, "Clutch and Brake Linings," L. P. Godfrey, 7.30 p.m.——WESTERN CENTRE: Royal Hotel, Bristol, "Fire Precautions in the Oil Industry," D. W. Thomas, 7.30 p.m.

Mon., Oct. 10th.—E. REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "Manumatic Transmission Control," J. St. H. Webb, 7.30 p.m.

INSTITUTE OF WELDING

Wed., Nov. 2nd, to Fri., Nov. 4th.—Autumn Meeting, London.

INSTITUTION OF CIVIL ENGINEERS

Tues., Oct. 4th.—AIRPORT MEETING: Great George Street, Westminster, London, S.W.1, "Selected Aspects of the Geometric Design of Airports," John Hugh Jones, 5.30 p.m.——N.W. ASSOCIATION: Reynolds' Hall, College of Technology, Manchester, "The Architectural and Engineering Aspects of Building Design," E. Shepley and W. A. Gibbon, 6.45 p.m.

Wed., Oct. 5th.—N.W. ASSOCIATION: 9, The Temple, 24, Dale Street, Liverpool, "The Architectural and Engineering Aspects of Building Design," E. Shepley and W. A. Gibbon, 6.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Sat., Oct. 1st.—Visit to Brunswick Wharf Generating Station, 10.30 a.m.

Thurs., Oct. 6th.—ORDINARY MEETING: Savoy Place, London, W.C.2, Inaugural Address as President, Sir George H. Nelson, Bt., 5.30 p.m.

Mon., Oct. 10th.—LONDON GRADUATES' AND STUDENTS' SECTION: Savoy Place, London, W.C.2, Chairman's Address, "A.C. Switchgear," M. H. F. Collins, 6.30 p.m.

Tues., Oct. 11th.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Chairman's Address, W. Bamford 5.30 p.m.

INSTITUTION OF ENGINEERING INSPECTION

Tues., Oct. 4th.—COVENTRY BRANCH: Room A5, Technical College, Coventry, "Fabricating for the Electrical Engineering Industry," H. H. Reeve, 7.30 p.m.

Wed., Oct. 5th.—BIRMINGHAM BRANCH: Exchange and Engineering Centre, Birmingham, "The Manufacture, Inspection and Testing of Springs," C. Harris, 7.30 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Oct. 4th.—39, Elmbank Crescent, Glasgow, Presidential Address, A. M. Robb, 7.30 p.m.

INSTITUTION OF ENGINEERS-IN-CHARGE

Wed., Oct. 12th.—St. Bride's Institute, Bride Lane, Fleet Street, London, E.C.4, Presidential Address, R. L. Quertier, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Wed., Oct. 5th.—E. MIDLANDS BRANCH: The College of Technology, Leicester, "Snags in Thermostatic Control," F. M. H. Taylor, 6.45 p.m.

Thurs., Oct. 6th.—BIRMINGHAM AND DISTRICT BRANCH: Exchange and Engineering Centre, Birmingham, "Some Aspects of Industrial Air Conditioning," J. Carter, 6.30 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Fri., Oct. 7th.—LONDON BRANCH: Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "Aerial Surveys and Practical Application of Results Therefrom," Joint Papers, Hunting Aerosurveys, Ltd., and B. F. J. Bradbeer, 5.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Oct. 5th.—Institution of Mechanical Engineers, 1, Birdcage Walk, Westminster, London, S.W.1, "The British Railways Mechanical Iron Foundry, Horwich," S. A. S. Smith, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Fri., Oct. 7th.—AUTOMOBILE DIVISION: 1, Birdcage Walk, Westminster, London, S.W.1, Annual General Meeting. Address by Chairman of the Division, 5.30 p.m.

Tues., Oct. 11th.—EDUCATION GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, "The Place in Engineering Training of Metallurgical Knowledge and Instruction," 6.45 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Oct. 4th.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Radio Aids to Marine Navigation," W. Dolman, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., Oct. 3rd.—E. AND W. RIDINGS REGIONAL MEETING: Chemistry Lecture Theatre, The University, Leeds, 2, "Valid Incentives," E. C. Gordon England, 7 p.m.

Wed., Oct. 5th.—NOTTINGHAM SECTION: Victoria Station Hotel, Nottingham, "Packaging," E. H. Dickens, 7 p.m.——S. ESSEX SECTION: Mid-Essex Technical College, Chelmsford, "Training of Production Managers and Production Engineers," G. S. Bosworth, 7.30 p.m.

Thurs., Oct. 6th.—READING SECTION: Great Western Hotel, Reading, "Production Control as Applied to Small and Medium-Size Companies," F. T. Hunter, 7.30 p.m.

Mon., Oct. 10th.—HALIFAX SECTION: George Hotel, Huddersfield, "Automation—New Tools for Higher Productivity," F. G. Woollard, 7.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Oct. 4th.—NORTHERN COUNTIES BRANCH: Cleveland Scientific and Technical Institution, Middlesbrough, "Relationship Between Structural and Civil Engineering," E. A. Parsons, 6.30 p.m.

Thurs., Oct. 6th.—11, Upper Belgrave Street, London, S.W.1, Presidential Address, Stanley Vaughan, 6 p.m.

Fri., Oct. 7th.—W. COUNTIES BRANCH: The University, Bristol, Chairman's Address, N. G. T. Ball, 6 p.m.

INSTITUTION OF WORKS MANAGERS

Tues., Oct. 4th.—LONDON BRANCH: Waldorf Hotel, Aldwych, London, W.C.2, Annual General Meeting, Films on Material Handling, "The Case for Handling," "Time, Space and Effort," 6.45 p.m.

IRON AND STEEL INSTITUTE

Wed. to Fri., Oct. 12th to 14th.—Special Meeting in Scunthorpe.

KING'S COLLEGE, LONDON, FACULTY OF ENGINEERING

Fri., Oct. 7th.—PUBLIC LECTURE: King's College, Strand, London, W.C.2, "The University Scene in Australia," A. H. Willis, 5.30 p.m.

MANCHESTER GEOLOGICAL AND MINING SOCIETY

Thurs., Oct. 6th.—Mining and Technical College, Wigan, 117th Annual General Meeting, 3.15 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Oct. 14th.—OPENING GENERAL MEETING: Lecture Theatre, Literary and Philosophical Society, Newcastle upon Tyne, "The Impact of the Development of Atomic and Thermo-nuclear Weapons on the Royal Navy," J. R. H. Bull, 6.15 p.m.

ROYAL AERONAUTICAL SOCIETY

Thurs., Oct. 6th.—BRITISH COMMONWEALTH AND EMPIRE LECTURE: Royal Institution, 21, Albemarle Street, London, W.1, "The Growth of Aeronautical Research in Canada During the Post-War Decade," J. J. Green, 6 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., Oct. 10th.—VALUATION AND RATING GENERAL MEETING: 12, Great George Street, Westminster, London, S.W.1, "Valuation of Houses and Flats for Rating Purposes," H. D. S. Stiles, 5.30 p.m.

SHEET AND STRIP METAL USERS' TECHNICAL ASSOCIATION

Mon. and Tues., Oct. 10th and 11th.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Special Conference on Modern Materials.

SHEFFIELD METALLURGICAL ASSOCIATION

Tues., Oct. 4th.—B.I.S.R.A. Laboratories, Hoyle Street, Sheffield, 3, "Some Aspects of Materials for Aero-Engines," H. E. Gresham, 7 p.m.